Comparative Study of Surgical and Laser Management of Benign Chronic Subglottic Stenosis

Essay

Submitted for partial fulfillment of
The Master degree in Otolaryngology
BY

Hany Samir Mostafa Metwally
M.B.B.Ch.

Supervised by

Prof. Dr. Mohamed A. Hegazy
Prof. Of Otolaryngology
Faculty of Medicine
Cairo University

Dr. Hady Salah Abd El Azim
Lecturer of Otolaryngology
Faculty of Medicine
Cairo University

Dr. Sherif Safvvat Guindi
Lecturer of Otolaryngology
Faculty of Medicine
Cairo University, Fayoum Branch

Faculty of medicine
Cairo University
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ACKNOWLEDGMENT

I would like to express my sincere gratitude and appreciation to

Prof. Dr. Mohamed A. Hegazy

for his valuable advice and support that made this work attain its shape.

My appreciation is also extended to

Dr. Hady Salah Abd El Azim
Dr. Sherif Safwat Guindi

for their support, precious advice and encouragement throughout the preparation of this work.

Contents

INTRODUCTION

The management of patients with subglottic stenosis is a difficult and challenging problem that stems, in part, from the complexity of both the etiology of the disorder and the medical history of the patient with airway obstruction .On the other hand, the otolarygologist-head and neck surgeon faces a two fold challenge in treating the problem: (1) to accurately and precisely define the site(s) and nature of the obstruction and to choose an appropriate procedure for management. Airway obstruction can be of acute or chronic nature. Often the patient exists with a chronic compromise of the airway that is often tipped into an acute obstruction by coexisting or concurrent medical illness. In acute airway obstruction, patients have difficulty maintaining adequate levels of oxygenation, and therapy is directed at emergency relieving the obstruction. On the other hand, in chronic airway obstruction the respiratory problem develops gradually and patients compensate for their reduced respiratory capabilities by decreasing their physical activity producing a handicapping condition (Courey, 1995).

To better manage these patients, it is therefore necessary that the physician have a thorough understanding of the problem and its causes. This knowledge directs the choice of the proper management of every case individually.

Despite measures introduced to decrease the frequency and consequence of subglottic stenosis (safety belts in motor vehicle, advances in intensive care unit management, and modification in endotracheal and tracheostomy tube design) subglottic stenosis remains a formidable problem facing the otolarygologist - head and neck surgeon. Effective management of subglottic stenosis dictates a flexible, individualized approach and requires the physician to choose among a number of options (Wanamaker, and, Eliachar, 1995).
In this work, we highlight the available options for management of this disorder with special concern towards both the open surgical and the laser management of the problem through discussing the indications, technique,

results, and potential complications.

<u>Historical Perspective</u>

From a review of the recent literature one is left with the impression that laryngotracheal stenosis is a relatively recent problem that owes its origin to the practice of long term intubation. This may be true in neonates, but in children and adults it has been well described for over a century.

Mackenzie, (1880), in his book of diseases of the pharynx, larynx and trachea, recognized that a contracted laryngeal passage may develop as a result of syphilis, trauma, or many inflammatory conditions involving the upper airway. He used dilatation to treat these individuals but he faced disappointing results. More successful results were obtained by the treatment method practiced by Schoetter of Vienna. After dilating the larynx with rigid vulcanite tubes, he used short plugs of varying diameters as endolaryngeal stent. These were introduced into the larynx and remained in situ by means of tracheal cannula. This long-term dilatation eventually permitted some patients to be decannulated (Richard and Smith, 1987).

Koening, 1896, used the rib to repair a tracheal defect and, 4 years later, Von Mangoldt, 1900, reported the use of costal cartilage to repair tracheal fistula. Kindig, 1921, had done six successful tracheoplasties using this technique. Henscher, 1927, added an addition three cases and modified the technique by using clavicular bone (Richard and Smith, 1987).

Rethi, 1956, treated numerous cases of traumatic cicatricial laryngeal stenosis after world war (I). In an attempt to decannulate individuals in the shortest time possible, laryngofissure and bilateral division of the posterior cricoid plate at the junction of the lateral and posterior wall was done. This technique was later modified by a single posterior midline vertical incision in the cricoid plate and destruction of the cartilage until the convex fibrous wall of the esophagus was visible in the midline. A dilator was left in position while wound healing occurred (Rethi, 1956).

In contrast to Rethi, **Jackson and Jackson, (1937),** felt that incisions of the

cricoid plate and posterior laryngeal wall were a disaster to be avoided if at all possible. However, **Cotton et al. (1992**) introduced a technique of four quadrant cricoid division i.e. division of the anterior, posterior and lateral walls .

A number of material can be interposed in the fissure to increase the laryngo - tracheal circumference and the airway size such as bone from iliac crest, hyoid, clavicle or a rib(**Looper, 1938 , El - Barbary and Nour El-Din , 1957, Taha et al. 1981 and Zalzal et al, 1986)**

Also cartilage obtained from the auricle, costal margin, epiglottis, nasal septum or the thyroid ala have been tried **(Moryenstein, 1972; Toohill et al,, 1976; Zalzal, 1986; Duncavage et al .1989, Seid et al, 1991 and Lusk et al. 1993)** . The stemomastoid or sternohyoid muscle flaps have been used **(Eliachar and Moscona, 1981, Close et al. 1983, Friedmann and Mayer, 1992)** .The application of microvascular free - tissue transfer in laryngotracheal reconstruction has been applied using a fibula osseocutaneous revascularized flap (**Esclamado and Carroll, 1997).**

Open technique to repair laryngo - tracheal stenosis also include resection of the stenotic segment and end to end anastomosis **(Gerwat and Bryce, 1974, Grillo, 1982, Courand et al. 1985, Rifai 1989 and Macchiarini et al. 1993)** . Alternatively, synthetic materials such as marlex or dacron can be used to bridge the surgical defect (**Zalzal et al. 1986**) . Excision of the fibrous stricture and graft have been tried **(Montgomery, 1968, Taha et al, 1981 and Hegazy et al, 1992).**

A relatively recent treatment option is the use of endoscopic laser, as the laser fulfills the need to manipulate the tissue in the distal portion of the airway without necessitating an external incision, it can deliver energy to

achieve cutting, coagulation, or vaporization with great precision, good hemostasis, and less perioperative edema (Coleman et al. 1995).

Treatment options for the endoscopic laser treatment of stenotic segment include:

- Laser ablation of the stenosis that may be combined with dilatation of the stenotic segment, intraluminal stenting ,or both (Shapshay et al. 1989 , Hegazy and Dewidar ,1997).

- Micro-trapdoor technique is used in debulking stenotic areas that are confined to a single quadrant of the airway but may also be used for circumferential stenosis (Coleman and Ossoff, 1991, and Werkhaven et al. 1993).

- Radial incision and dilatation i.e. making radial incisions with the laser beam through the stenosis in five or six areas (Shapshay et al., 1987).

Given this number of treatment options, one has to evaluate an individual with laryngo-tracheal stenosis to formulate logic and appropriate treatment plan.

Surgical Anatomy of the Larynx

The human larynx is a highly specialized organ that has developed from a simple valve, designed to allow passage of air and prevent entrance of food or liquid, into a sophisticated structure adapted for complex phonatory function (Kirchner, 1993). The development of phonatory abilities necessary for speech and language development has caused minimal compromise of the larynx's primary role as guardian of the lungs. These adaptations are reflected by the lowered position of the larynx in the neck, the size shape, and relationship of the laryngeal cartilages, the design and vibratory characteristics of the vocal folds, and changes in the remainder of the phonatory tract (Pracy, 1983).

Laryngeal Framework:

The laryngeal framework is composed of nine cartilages, three unpaired cartilages and three sets of paired cartilages. These cartilages are interconnected by a complex arrangement of fibrous ligaments, joints, and connective tissue bands, forming a framework that defines the general shape of the larynx. The larynx occupies a position anterior to the sixth and seventh cervical vertebrae and is suspended superior to the hyoid bone, inferior to the trachea, and posterior to the inferior constrictor muscles of the pharynx (Fig.l).

The cricoid cartilage is the first of the three unpaired cartilages of the larynx. It is the only cartilage of the larynx or trachea that forms a complete ring surrounding the airway. This property predisposes the cricoid to injury, making it a common site of airway narrowing. The cricoid cartilage takes the shape of an eccentric signet ring, widest at the posterior lamina. The inferior border is flat, whereas the superior border is elevated posteriorly above the plane of the anterior cricoid lamina. The subglottic space lies internal to the cricoid cartilage and, in the infant, forms the narrowest portion the airway.

The thyroid cartilage is the second unpaired cartilage; it is composed of two laminae attached at the midline. The two laminae form a variable angle approximately 75 to 90 degrees in the adult male, and 90 to 110 degrees in the adult female (Roncallo, 1988). The junction of the two thyroid laminae forms the laryngeal prominence. The superior thyroid notch lies at the point of divergence of the thyroid laminae at the laryngeal prominence. Superior and inferior cornua emerge from the posterior aspect of the thyroid cartilage and attach to the hyoid bone and
cricoid cartilage, respectively. The superior tubercle forms a prominence on the upper border of the thyroid cartilage, and the inferior tubercle, on the lower border of the cartilage. Between these two prominences lies the oblique line, demarcating

the insertion point for the sternothyroid muscles, the thyrohyoid muscles, and the inferior pharyngeal constrictor muscles.

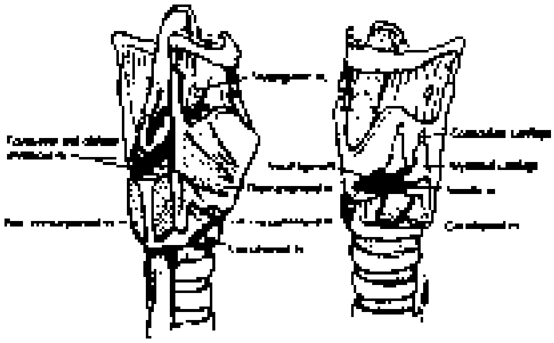


Figure L Laryngeal cartilages and musculature.

The epiglottis is the third impaired laryngeal cartilage. Unlike the other laryngeal cartilages, it is composed of elastic cartilage; thus, it is more flexible and is not subject to ossification. The epiglottis attaches to the thyroid cartilage by the thyroepiglottic ligament, and the hyoid bone, by the hyoepiglottic ligament. Connective tissue bands between the tongue and the epiglottis produce a median and two lateral glossoepiglottic folds.

Lying on the cricoid cartilages are paired arytenoid cartilages; each shaped like a triangle-based pyramid with a concave articulation on the inferior surface. Medially, the vocal process attaches to the vocal ligament, and posterolaterally, the muscular process attaches to the posterior cricoarytenoid muscle. The two remaining sets of paired cartilages are the comiculate and cuneiform cartilages, which lie in the quadrangular membrane between the arytenoid cartilage and the epiglottis. The comiculate cartilage lies on top of the arytenoid cartilage, elevating the height of the aryepiglottic fold. The cuneiform cartilage lies in the aryepiglottic fold and acts as a batten to stiffen the fold.

Ossification commonly occurs in the laryngeal cartilages and starts during the second or third decade of life. Thyroid ossification starts near the inferior cornu of the thyroid cartilage and spreads anteriorly along the inferior border and superiorly along the posterior border. Separate ossification sites develop along the superior aspect of the thyroid laminae and at the superior thyroid notch. Ossification of the cricoid cartilage begins on the upper border of the posterior cricoid lamina and spreads along the superior border of the cartilage and the remainder of the posterior lamina. The anterior portion of the cricoid is the last to ossify Arytenoid ossification

starts in the muscular process and can extend to the base of the arytenoid. The presence and extent of ossification influence the susceptibility and patterns of injury and fracture of the larynx with trauma. Ossification may also be mistaken on radiographs for a foreign body (Hately, 1985).

The connective tissue of the larynx can be subdivided into extrinsic ligaments, connecting the larynx to the hyoid bone and the trachea, and intrinsic ligaments, between the laryngeal cartilages. The thyroid cartilage is suspended from the hyoid bone by the thyrohyoid membrane and the lateral thyrohyoid ligaments. The lateral thyrohyoid ligament connects the greater cornu of the hyoid bone to the superior cornu of the thyroid cartilage. The epiglottis is suspended form the hyoid bone by the hyoepiglottic ligament passing between the anterior surface of the epiglottis and the upper border of the medial hyoid bone. The glossoepiglottic ligament connects the epiglottis to the tongue base through a midline fold and two lateral tissue folds. Inferiorly, the cricotracheal ligament attaches the cricoid cartilage to the first tracheal ring.

The intrinsic ligaments of the larynx form an elastic framework that holds the nine intrinsic laryngeal cartilages in position and defines the skeletal outline of the larynx (Fig.2). The quadrangular membrane spans the space between the lateral surface of the epiglottis anteriorly, the medial surface of the arytenoid cartilage posteriorly, and the ventricular ligament inferiorly. The superior margin of the quadrangular membrane forms the edge of the aryepiglottic (AE) fold. The conus elasticus arises on the superior border of the cricoid cartilage. Superiorly, it attaches to the lower anterior border of the thyroid cartilage, forming the cricothyroid membrane. The superior aspect of the conus elasticus is continuous laterally with the vocal ligament, and the posterior attachment of the conus elasticus is to the vocal process of the arytenoid cartilage. The conus elasticus lies in a submucosal plane in the subglottis, and anteriorly, the cricothyroid membrane lies beneath the subcutaneous tissue. The thyroepiglottic ligament attaches the base of the epiglottis to the inner surface of the thyroid lamina just below the superior thyroid notch. The inferior cornu of the thyroid cartilage articulates with the articular facet of the cricoid cartilage and is held in placed by lateral and posterior cricothyroid ligaments.

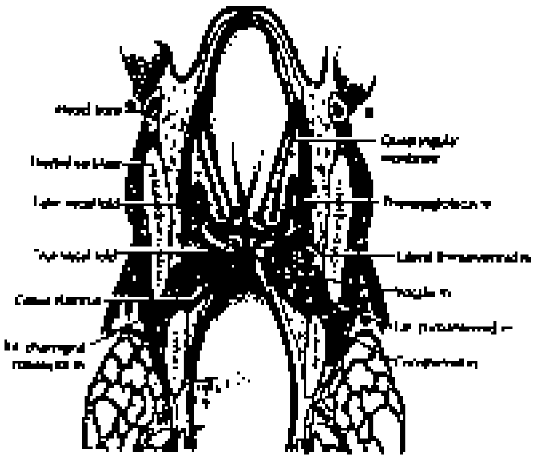


Figure 2. Cross-section of larynx, midportion.

The cricothyroid joint, surrounded by the cricothyroid ligaments, is a diarthroidal synovial joint, which allows rotatory motion of the cricoid cartilage on the inferior cornua of the thyroid cartilage as well as limited gliding motion. The cricoid and arytenoid cartilages similarly form a diarthrodial synovial cricoarytenoid joint. The arytenoid cartilage is supported on the cricoid cartilage by the posterior criocarytenoid ligament, which extends from the cricoid cartilage to the medial and posterior body of the arytenoid cartilage. Anteriorly, the arytenoid cartilage attaches to the vocal ligament at the vocal process. The vocal ligament passes form the vocal process to the anterior midline thyroid cartilage, inserting at Broyles ligament. Posterolaterally, the posterior cricoarytenoid muscle inserts into the muscular process of the arytenoid cartilage. The vestibular ligament attaches anteriorly to the thyroid cartilage, between the insertions of the thyroepiglottic ligament and vocal ligaments, and attaches posteriorly to the anterolateral surface of the arytenoid cartilage just above the insertion of the vocal ligament. The apex of the arytenoid cartilage attaches to the posterior edge of the quadrangular membrane.

Muscles of the Larynx:

The laryngeal ip muscles, which s with origins anc muscles included geniohyoid, dig^ stylopharyngeal sternothyroid, st middle constrictor constrictor muscle aspect of the crico

usculature can be divided into extrinsic laryngeal upport the laryngeal framework, and intrinsic muscles, insertions within the larynx proper. The extrinsic the suprahyoid musculature, made up of the stric, hyoglossal, mylohyoid, stylohyoid, and rhuscles, and the infrahyoid musculature, made up of the emohyoid, thyrohyoid, and omohyoid muscles. The muscle attaches to the hyoid bone, and the inferior to the oblique line of the thyroid lamina and the lateral id cartilage.

The intrinsic laryngeal muscles and their respective innervations and muscle actions are listed in (Tablel). The five intrinsic muscles are the cricothyroid muscle, the posterior cricoarytenoid muscle, the lateral cricoarytenoid muscle, the thyroarytenoid muscle, and the interarytenoid (arytenoid) muscle. The cricothyroid muscle originates along the lateral aspect of the outer surface of the cricoid cartilage and inserts along the inferior thyroid comu and lower posterior lamina of the thyroid cartilage. This is the only piuscle innervated by the

laryngeal nerve, the posterior lami

external branch of the superior he posterior cricoarytenoid muscle (PCA) arises from iba of the cricoid cartilage. Its fibers travel superiorly

and laterally to insert into the posterior surface of the muscular process of the arytenoid cartilage. The PCA muscle is the sole abductor muscle of the larynx. The lateral cricoarytenoid muscle arises form the superior border of the cricoid cartilage and insets into the front of the muscular process of the arytenoid cartilage. The thyroarytenoid muscle arises form a broad attachment along the lower anterior portion of the thyroid lamina

and the superior divisions of this m the vocal ligamen

portion of the middle cricothyroid ligament. Three uscle have been described. The most fibers, adjacent to ;, insert into the vocal process of the arytenoid cartilage and are referred fo as the vocalis muscle. Muscle fibers lateral to the vocalis muscle form the thyroarytenoid muscle proper and attach to the anterior body of the arytenoid cartilage. The third group of muscle fibers consists of a small number of fibers from the lateral aspect of the thyroarytenoid muscle that pass superiorly and attach to the aryepiglottic fold and the epiglottis (see Table I). The interarytenoid muscle is an unpaired muscle made up of oblique and transverse fibers connecting the posterior surfaces of the two arytenoid cartilages. A small band of fibers form the oblique arytenoid muscle may extend along the AE fold, forming an aryepiglottic muscle band.

Table 1. Laryngeal musculature

Muscle	Innervation	Dominant Muscle Action
Cricothyroid	External Branch of Superior laryngeal nerve	Vocal cord elongation and tension
Posterior cricoarytenoid	Recurrent laryngeal nerve	Vocal fold adduction
Lateral cricoarytenoid	Recurrent laryngeal nerve	Vocal fold adduction
Thyroarytenoid (vocaiis)	Recurrent laryngeal nerve	Vocal fold adduction
Lateral thyroarytenoid	Recurrent laryngeal nerve	Tense vocal fold
Thyroeopiglotticus	Recurrent laryngeal nerve	Vocal fold adduction
Interarytenoid	Recurrent laryngeal nerve	Vocal fold shortening
Transverse fibers	Recurrent laryngeal nerve	Adduct arytenoids
Oblique fibers	Recurrent laryngeal nerve	Close the laryngeal introitus

Innervation of the Larynx:

The larynx receives innervation from the vagus nerve via the superior and recurrent laryngeal nerves (Fig.3). The superior laryngeal nerve originates near the lower end of the inferior (nodose) vagal ganglion and travels inferiority, under and then medial to the internal carotid artery. The nerve travels along the pharyngeal constrictors and divides into internal and external branches near the greater cornu of the hyoid bone. The internal branch travels with the superior laryngeal artery and pierces the thyrohyoid membrane. The internal division divides into multiple branches and provides sensation to the supraglottic larynx as well as

innervation to minor salivary glands in the region. The external branch of the superior laryngeal nerve travels along the inferior constrictor muscle, passes deep to the sternothyroid muscle, and innervates the cricothyroid muscle. The external branch also sends fibers to the pharyngeal plexus and the inferior pharyngeal constrictor muscle.

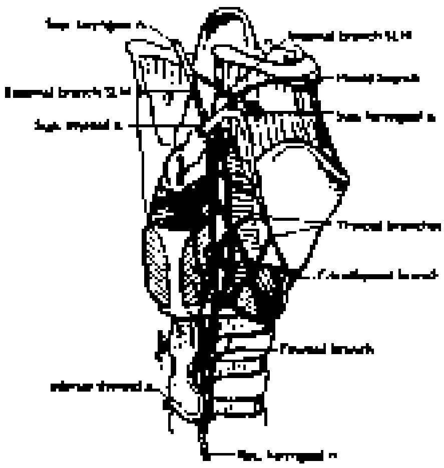


Figure 3. Arterial blood supply and innervation of the larynx.

The right recurrent laryngeal nerve leaves the vagus nerve near the right subclavian artery, passes under and behind the artery, and travels to the right tracheoesophageal groove. The left recurrent nerve passes under and behind the aortic arch, distal to the ligament arteriosum, and enters the tracheoesophageal groove in the chest. During their superior course toward the larynx, branches are distributed to the esophagus, the trachea, and the inferior pharyngeal constrictor. These branches are more numerous on the left side (Clemente, 1985). The nerves pass medial to the lateral lobes of the thyroid gland and are closely related to the inferior the lateral lobes of the thyroid gland and are closely related to the inferior thyroid artery. Both nerves enter the larynx behind the cricothyroid joint, deep to the fibers of the inferior constrictor muscle. The recurrent nerve splits into an anterior division that supplies the adductors of the larynx and a posterior division that supplies the posterior cricoarytenoid muscle. This division may occur outside the larynx, and a posterior division that supplies the posterior cricoarytenoid muscle.

This division may occur outside the larynx, and in one study, division of the nerve was found to occur more than 5mm below the inferior border of the cricoid cartilage in 747 of 1177 recurrent nerves visualized (Katz, 1993). Occasionally an anterior branch may enter the larynx anterior to the cricothyroid joint (Tuker, 1993), Fibers from the recurrent nerve pass superiorly, behind the cricoid cartilage, and anastomose with fibers form the internal branch of the superior laryngeal nerve also been described. Using

special nerve staining and microdissection techniques, sanders et al.,(1993), have demonstrated multiple anastomoses from the recurrent laryngeal nerve, to both the internal and external branches of the superior laryngeal nerve of the human larynx.

Blood supply to the Larynx:

The arterial blood supply to the larynx arises from the superior and inferior laryngeal branches of the superior and inferior thyroid arteries (see Fig.3). The superior laryngeal artery is the largest branch of the superior thyroid artery. It joins the internal branch of the superior laryngeal thyroid artery. It joins the internal branch of the superior laryngeal nerve near the greater cornu of the thyroid cartilage, travels deep to the thyrohyoid muscle, and usually pierces the thyrohyoid membrane. Occasionally, the superior laryngeal artery enters the larynx more inferiorly through a foramen in the thyroid lamina or rarely, through the cricothyroid ligament. The superior laryngeal artery has interconnecting branches to the inferior laryngeal artery in the larynx. A cricothyroid branch of the superior thyroid artery passes along the inferior constrictor muscle and the superior aspect of the cricothyroid muscle, joining its counterpart from the opposite side on the superior surface of the cricothyroid membrane. The inferior laryngeal artery travels with the recurrent the inferior pharyngeal constrictor muscle. The artery divides into multiple branches and has interconnections with branches of the superior laryngeal artery and the opposite inferior laryngeal artery (Pearson, 1975).

The venous drainage of the larynx roughly parallels the arterial distribution. Veins traveling with the superior laryngeal artery join the superior thyroid vein and empty into the internal jugular vein. Veins traveling with the inferior thyroid artery join the middle thyroid vein and also enter the internal jugular vein. Veins arising near the cricothyroid membrane drain into the thyroid isthmus and the inferior thyroid veins.

Lymphatic Drainage of the Larynx:

Lymphatic drainage patterns have been described by Pressman, (1956), from intravital dye studies. Supraglottic lymphatics cross the midline freely in the preepiglottic space and exit via the thyrohyoid membrane.
These lymphatics drain into the superior and middle jugular lymph nodes. The free edge of the vocal cord is devoid of lymphatics. The subglottic lymph drainage is through the cricothyroid membrane laterally to the paratracheal nodes and medially to the Delphian node. Crossover of the subglottic lymphatics occurs but not the same extent as in the supraglottis (Pressman,

1956).

Mucosal Anatomy of the Larynx:

The mucosa of the larynx is composed predominantly of respiratory epithelium (pseudostratified ciliated columnar epithelium with goblet cells). The vocal folds, the anterior surface and upper portion of the posterior surface of the epiglottis, the edges of the AE folds and portions of the pyriform fossa are covered with stratified squamous epithelium. The amount and distribution of squamous epithelium are variable (Steli, et aL, 1982). Mucussecreting glands are present throughout the laryngeal mucosa and are most prominent on the epiglottis, in from of the arytenoid cartilages, and in the ventricles and saccules (Ham and Cormack, 1979).

Infant and Pediatric Larynx:

The infant larynx has many minor anatomic differences form the adult larynx. The component parts are the same, but the relative size and position of the components vary. These differences rapidly become less pronounced as the child ages. At birth, the larynx is situated high in the neck, with the base of the cricoid lying at roughly the level of the fourth cervical vertebra (C4) (Sasaki, 1977). The epiglottis rises superiorly and lies against the nasopharyngeal surface of the soft palate, making the neonate an obligate nasal breather during the first 4 to 6 months of life. By adolescence, the larynx has descended to the C6 level. The laryngeal cartilages and soft tissues are more pliant in the infant and child, and the soft tissues less tightly adherent to the underlying cartilages. This makes the soft tissues more susceptible to collapse into the airway and less resistant to developing severe submucosal edema. The epiglottis has a narrow base of attachment to the thyroid cartilage and is more tubular, shaped like the Greek letter omega In addition, it forms a more acute angle with the larynx (Ferguson, 1970). These characteristics predispose the soft tissues of the larynx to collapse on deep inspiration. The vocal cord length in the infant is 6 to 8 mm, and the arytenoid is adult size at birth. The vocal process in the infant constitutes approximately 50% of the length of the vocal cord. The adult vocal cord length is approximately 14 to 23mm, and the vocal process constitutes approximately one third of

the vocal cord length (Reichert, 1987). The subglottic larynx is the narrowest portion of the pediatric airway, whereas in the adult, the glottis forms the narrowest part of the upper respiratory tract. The normal infant subglottic diameter is 5 to 7mm and a diameter of 4 mm or less is diagnostic of subglottic stenosis.

Aetiology

Subglottic stenosis (SGS) is a challenging complex clinical problem, that has a complex etiology .In the early to middle part of this century, SGS has been frequently sequelae of infection or trauma, but more recently, endotracheal intubation, while providing requisite respiratory support, has precipitated many cases of acquired subglottic stenosis .In addition some children are bom with a narrowed subglottic lumen (congenital SGS). Patients may rarely develop stenosis without prior airway manipulation (idiopathic SGS).

*** Aetiology of Subglottic Stenosis :**

1- Trauma:

A-External laryngeal trauma :

- Blunt neck trauma .
- Penetrating wound of the larynx .
- High tracheostomy in children .

B-Internal laryngeal trauma :

- Prolonged endotracheal intubation .
- Post surgical.
- Post radiation.
- Endotracheal bum.

2- Chronic inflammatory disease

3- Laryngeal neoplasms

4 -Congenital subglottic stenosis 5-

Idiopathic subglottic stenosis

1- <u>Larvngeal Trauma</u>

A. External laryngeal trauma

Neglected, maldiagnosed or maltreated trauma is the most common cause of chronic acquired laryngeal stenosis in children and adults. The laryngeal spaces are important in the creation of stenosis after injury. These spaces are readily distended by blood after injury. If blood is not evacuated, two pathological problems may occur: 1) absorption of hematoma by macrophages 2) invasion or organization with deposition of fibrous tissue. The collagen in fibrous tissue later contracts, causing stenosis and loss of mobility **(Cotton and Zalzal, 1988)** **.**

1. Blunt trauma to neck

It occurs during motor vehicle injuries of the larynx when the anterior surface of the extended neck strikes the dashboard or steering wheel causing a laryngeal framework fracture. This is more common in adults than in children in whom prominent mandible and relatively high position of the larynx protect the latter from injury **(Maran et al., 1981).**

Chronic acquired stenosis occurs as sequelae of severe laryngeal trauma especially if inadequately managed. In many cases, the cricoid injury is associated with crushing and separation of upper tracheal rings. As subglottic edema increases, airway obstruction rapidly appears, hoarseness is not marked unless the recurrent laryngeal nerves have been injured **(Schaefer, 1982).**

Airway obstruction necessitates life saving tracheostomy and immediate open reduction and internal fixation, avoiding the use of an indwelling stent whenever

possible **(Dedo and Rowe, 1983).**

It is due to infection, healing is delayed and excessive granulation and fibrous tissue are produced. Since the cricoid cartilage is circular and located at the narrowest point of the laryngeal lumen, minor injuries if untreated may lead to subglottic stenosis. **(Pennington, 1972).**

2- Laryngeotracheal separation

It occurs upon hyperextension of the neck on striking a cable. The trachea become compressed and separated from the cricoid even without breaking the skin (Alonso, 1974)

3- Penetration wounds of the larynx

They are usually less common in children than in adults.

4- High tracheostomy or cricothyrodotomy

They both cause subglottic stenosis, as the cricothyroid space is usually is not more than 7 mm in its vertical dimension as measured in adult male larynx, and may be further narrowed by action of the cricothyroid muscle, so it is usually smaller than the outeT dimension of most tracheostomy tubes, increasing the risk of cartilage injury is high.

A combination of pressure against the cricoid cartilage together with the action of the shearing forces of the cricothyroid muscle and in addition to concomitant infection create a favorable environment for chondritis, necrosis and ultimately subglottic stenosis (kuriloff et al., 1989).

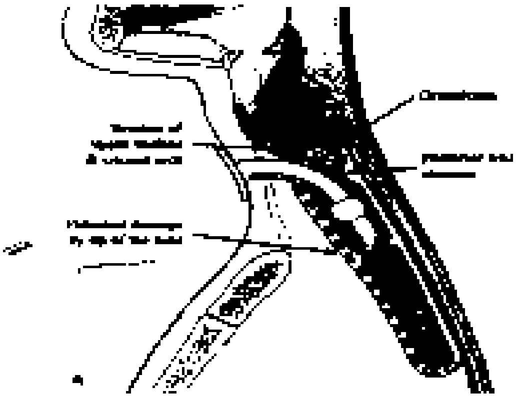


Figure 4,The potential problems associated with thestandard Curved tracheostomy tube.

B - Internal laryngeal trauma

(l) -Endotracheal intubation:

Approximately 90%of acquired chronic subglottic stenosis in infants and children occur secondary to endotracheal intubation due to variety of reasons:

- The cricoid cartilage is the only area in the upper airway that has a complete circular ring, preventing the outward extension of the traumatic edema.

- The pseudostratified, ciliated, columnar respiratory epithelium lining the subglottic region is delicate and tends to deteriorate under the indwelling tube.

- The subglottic mucosa is made of loose areolar tissues that allow edema to develop quickly and easily.

- The subglottic region is the narrowest portion of the pediatric airway **(Holinger et al. 1976).**

According to **Grund, (1990),** the incidence of acquired subglottic stenosis after intubation varies between pediatric and adult data and ranges between l%-8% respectively. However, the figures underestimate the true incidence in pediatric population because many infants who are intubated do not survive the primary illness. Also some cases of acquired subglottic stenosis may not be recognized unless an infection of the upper respiratory tract develops later in life.

In adults, traumatic intubation denudes the mucosa, in the posterior commissure

causing ulceration that heals by secondary intention. Collagen is deposited and contracts to form a posterior glottic scaring, that fixes the arytenoid towards the middle line **(Fee and wilson, 1979).**

The endotracheal tube causes pressure on the mucosa, the posterior cricoid plate mucosa appears to be the most vulnerable to the traumatic effects of the intubation followed by damage to the epithelium overlying the arytenoid because maximal pressure between two unyielding surfaces accurs here.

The earliest effect would appear to be loss of the ciliary streaming secondary to cuff pressure against the epithelium but the muco - cilliary mechanism recovers after removal of the tube.

Movement of the cuff is believed to produce a shearing force responsible for the development of a plane of cleavage parallel to the surface of the epithelium for about half way between surface and the basement membrane. The stage is set for ultimate development of exposure of the cricoid or tracheal ring pericondrium with ultimate pericondritis (Fee and Wilson, 1979).

It appears likely that the great majority of patients undergoing general anesthesia suffer these superficial lesions and heal uneventfully^.If the basement membrane is intact, if absent, healing time is doubled but still results in a normal larynx. Deep ulceration, on the other hand, is less common but more often complicated by granuloma and stenosis is due to prolonged healing time (Fee and Wilson, 1979). =

Primary healing of laryngeal injuries is hindered by the presence of loose and mobile subglottic mucosa, poor blood supply of cartilage and constant motion of the larynx associated with swallowing and head movement (Healy, 1982).

Predisposing factors in development of subglottic stenosis after <u>prolonged endotracheal intubation</u> 1-Duration of intubation

There is no definite safe time limit for endotracheal intubation, and severe injuries have been reported after 17 hours of intubation in adults (Bergstrom, 1962)

Whited, (1984), reported in a series of 200 adult patients having long term intubation, that a period of 7 to 10 days is acceptable, after which prolongation of

intubation is accompanied by increased incidence of acquired subglottic stenosis.
Neonates tolerate intubation up to 3 weeks due to:

a- relative immaturity of the laryngeal cartilages as they are hyper cellular with scanty gel like matrix rendering them more pliable , thus yielding to pressure (Hawkins, 1978) b- The high location of the neonatal larynx in the neck with its posterior tilt and funnel shape (Healy, 1982).

2-Size of the tube

Langman, et aL, (1989), reported the suitable size of endotracheal tube in relation to age.

The cuff pressure of the endotracheal tube is minimized by the use of high volume low-pressure balloons. Regular checks to keep cuff pressure at about 8 cm water is required.

AGE (YEARS)	Cuffed endotracheal tube (Inner diameter in mm.)	
	Oral intubation	ICU
0-2	2.5	2.5
2-6	3.0	3.0
6-12	3.5	4.0
12-20	4.5	4.5
Adult female	5.5	5.5
Adult male	5.5	6.0

Table (2)

. 3-Type of the tube (physical and chemical properties)

Silastic and polyvinyl chloride are considered the safest materials for prolonged intubation, as they are less irritating, but softer, easily compressed.
Ethylene oxide sterilization of polyvinyl chloride tubes produce troublesome toxic residues that causes chemical irritation (Santos et ah,
1989)

4- Shearing motion of the tube

It causes abrasive traumatic action on the mucosa in the area of the tube tissue interface in posterior larynx especially in restless patients, patients on respirators and with oro-tracheal intubation. The interarytenoid space serves as a fulcrum for the see -saw action of the endotracheal tube.

Significant injury in this site results in disturbed laryngeal physiology for both airway and sphincteric functions, **(Whitted, 1984).**

5- Infection

Sasaki, C.T. (1979) reported that superimposed infection compounds the mechanical mucosaf'trauma by increasing the inflammatory response and scar tissue.

Naso-gastric tube can cause pressure necrosis and cricoid chondritis if placed in the midline, coexistence of endotracheal and nasogastric tubes may increase the laryngeal complication by promoting gastro-esophageal reflux **(Freidman, 1984)**

(2) -Post surgical:

Acquired anterior glottic web can occur after excision of a laryngeal polyp or papilloma located in the anterior commissure if the anterior portion of both vocal cords are denuded simultaneously **(Rinne et al, 1983).**

Stell et al. (1985), reported subglottic stenosis after vertical or horizontal laryngectomy especially if excess tissue is removed without stenting.

Kuriloff et al. (1989) reported the increased incidence of acquired subglottic stenosis, as an airway problem, sequelae to an elective crico - thyroidotomy done in cardio -thoracic surgical patient for management of tracheo - bronchial secretion and prolonged ventilatory support.

(3) -Post irradiation

Chondro-radio necrosis occurring after radiation therapy can lead to scaring and stenosis either shortly after radiotherapy or as long as 20 years later. **(Montgomery, 1982).**

(4) -Endo -tracheal burn

Intra laryngeal bums from fumes smoke inhalation or caustic ingestion can give rise to subglottic stenosis **(Cudmore and Vivori,1981).**

2- Chronic Inflammatory Disease

A- Chronic granulomatous diseases

In laryngeal scleroma, sarcoidosis and syphilis.

(I) *Laryngeal Scleroma*

Is a chronic granulomatous disease endemic in EGYPT .It has a gradual onset affecting the upper respiratory tract, usually the nose and extending gradually backwards into the pharynx and the larynx and sometimes the trachea and bronchi (Freidman et aL, 1986)

Pathology:

*Aetio-pathogenesis:

Scleroma has been reported from more than 68 countries. Highly endemic regions with hundreds of reported cases exist in Guatemala, El Salvador, Venezuela, Egypt, Italy, South Western Russia and Colombia (Muzka and Gubina, 1971)

In Egypt, scleroma is endemic especially in certain areas such as Sharkia, Gharbia and Kaliobia. Many early reports were presented by Botros et al. (1954), Mosallam and Attia (1956) and Handousa and EIwi (1958).

*Age group:

Scleroma affects persons in different age groups. Quevedo (1949) stated that scleroma is a disease rarely seen in children and the youngest age in his study was a girl 8 years old and the oldest was a man 68 years old. Brescia et al. (1954) reported scleroma in a newly bora infant and named it scleroma neonatorum. Recently studies stated that the disease occur mainly in young adults, although it has been seen in almost any age (Weir, 1987; Rifai, 1989; and Hegazy et al., 1992).
*Sex:

Some authors stated that scleroma affects males more than females. Others reported that it affects both sexes equally (Yassin, 1950). The majority of authors agree that scleroma affects females more than males (Gaafar and Helmi,

1984).

*Causative organism:

Von Frisch (1882) reported the isolation of Gram negative encapsulated bacillus from scleroma patients, which was called Klebsiella rhinoscleromatis. The organism is an encapsulated, short, thick rod about

1- 2 micron long, 0.8micron wide, with parallel or bulging sides and rounded or slightly pointed ends. The bacillus is arranged in pairs, end to end and sometimes they are arranged singly. They are non-motile, non sporing and are Gram negative.

*Histopathological features:

Histopathological features of scleroma include Frisch bacilli, Miculicz cells, Russell bodies, plasma cells and neutrophils. These criteria make the diagnosis of scleroma certain (Quevedo, 1949).

By electron microscope, the epithelium shows metaplasia to stratified squamous epithelium of variable thickness, infrequently, focal areas of atrophy and flattening of the cells and loss of stratification are seen, denoting the possible ulcer formation. The cytoplasm of these flattened cells was filled with granular material and the nuclei are rounded and centrally placed. In certain areas, the intracellular spaces are widened by edema fluid compressing the epithelial cells. They contained granular material and rhinoscleroma bacilli exhibiting intercellular morphology, a thick slime layer and retain the integrity of their cell walls (Toppozada et al.1981).

*Clinico-pathological features:

The primary site of the scleroma is almost always the nasal cavity then, it extends backward to the pharynx, larynx and trachea or may extend forward into the upper lip and laterally into the sinuses. The superior meatus and olfactory cleft are usually spared (Zwiefach, 1955).
In the larynx the subglottic region is a common site for stenosis .The mucosa of the subglottic area is characterized by being thin, the subepithelial tissue is loose and the diameter of the larynx is relatively narrow, so that this part is prone to stenosis. El Barbary and Nour el din (1957), also found that scleroma has a predilection to this part, as it is the site of change in the type of mucosal lining from a stratified squamous epithelium to a columnar epithelium (El barbary and Nour el din, 1957)

Scleroma could be divided clinically and clinico-pathologically into the following stages:

1- The early catarrhal stage:

This stage is characterized by edema and subcutaneous tissue infiltration.

2- The atrophic stage:

This stage was given the name of rhinitis stage (Reyes, 1946 and Zwiefach, 1955) or the first stage (Quevedo, 1949). The mucosa in this stage appears thin, dry and covered by small thin greyish crusts. There is diffuse infiltration of the submucosal tissues. In the larynx the only symptom is usually dry cough (Botros et al.1954).

3- The granulomatous stage:

This stage is called infiltration period (Reyes, 1946), and second stage (Quevedo, 1949). In this stage different pictures could be seen such as discrete small granulomata while the remaining mucosa appears atrophic, localized nodule, granuloma that bleed profusely on touch or diffuse granulomatous infiltration of the submucosa with ulceration and adherent scabs removed with difficulty revealing raw bleeding sites.

In the larynx and trachea patients complain of cough, dyspnea and stridor both inspiratory and expiratory in advanced cases (Botros et aL, 1954).

4- The fibrotic stage:

Also called nodular period (Reyes, 1946), third stage (Quevedo, 1949), and cicatricial stage (Kline and Brody, 1949).

This stage is due to change of the granulomatous tissue into hard contracting fibrous tissue resulting in distorting the shape of the granulomatous masses and hardness or cartilaginous feeling, leading to laryngeo-tracheal obstruction.

These stages merge into each other and overlap in the whole upper respiratory tract (Botros et all954).

(II) Laryngeal sarcoidosis

Sarcoidosis is a chronic idiopathic granulomatous disease, also known as Besnier-Boeck disease. It may affect several organs and the mediastinal lymph

nodes are usually involved. Head and neck manifestations are found in 10% of patients of whom only a minor proportion have laryngeal disease. The disease is usually self-limiting. Laryngeal sarcoidosis may be the sole site of involvement in 50% of all patients whose disease affects the larynx **(Neel and McDonald, 1982).**

***Pathology:**

The pathology of the laryngeal lesion resembles a non-specific granuloma similar to the lesion in other organs. The granulomas are composed of epithelioid cells with a varying number of lymphocytes and plasma cells. Giant cells with inclusion bodies are few and necrosis and caseation are not found. Later fibrosis and hyalinization and possible encapsulation by fibrous tissue are more apparent **(van den Broek, 1997)**

^Clinical features:

Usually the patient has a history of hoarseness, dysphagia, and dyspnea. In most patients the main site is the supraglottis. The epiglottis and the false cords are swollen, edematous and pale, and the rim of the epiglottis is full and rounded. The true vocal cords and the subglottis are rarely affected. The lesion can progress rapidly and lead to life-threatening airway obstruction. The diagnosis is made by biopsy, which reveals the granulomatous nature of the lesion **(van den Broek, 1997).**

(III) Laryngeal Syphilis:

With the improvement in the treatment of syphilis, laryngeal syphilis is now rare. Involvement of the larynx is present in about 5% and syphilitic infection of the larynx should always be considered whenever an unexplained infection is present.

All stages of this disease can manifest in larynx. A primary lesion has been described very rarely. Small mucosal erosion develops into a typical primary chancre. The secondary stage is also rare and multiple vesicles and papular lesions extend into the larynx from the pharyngeal mucosa. The third stage appears after a symptom-free period, sometimes of many years, and is the most important. Granulomas are found in the mucosa and form a gumma. These are characterized by a center of necrotic amorphous tissue surrounded by an infiltrate of plasma cells and lymphocytes, sometimes with eosinophils and giant cells. There is periarterial infiltration and obliterative endarteritis. The presentation of syphilis in the larynx is very similar to other granulomatous diseases. Hoarseness and sometimes dysphagia are the primary symptoms. Pain is rare and indicates very rapid destruction of the deeper structures **(Benjamin,**

and Croxon, 1985)

B- Chronic systemic diseases:

(I) Relapsing polychondritis

Relapsing polychondritis is a rare condition that was first described in 1923 by Jaksch-Watenhorst. There is recurrent inflammation of cartilage especially of the auricle, nose and trachea. The etiology is unknown, but it is thought to be an autoimmune disease linked to the collagen vascular group of diseases. Patients with relapsing polychondritis suffer from rheumatoid arthritis, systemic lupus erythematosus or ankylosing spondylitis.

The recurrent inflammation in the cartilages of the head and neck region such as the pinna, nasal cartilages, larynx or trachea, is the most prominent manifestation, but inflammatory lesions such as scleritis, keratitis, arthropathy and vasculitis can be found in other supporting tissues **(Dolan et aL, 1966).**

The laryngeal and tracheal lesions manifest themselves with signs of laryngitis and tracheitis. The mucosa is swollen especially around he epiglottis and extending downwards into the trachea. In the later stages the cartilage disappears and the epiglottis may be shrunken. The other laryngeal cartilages may also be soft and tender. Loss of cartilage of the larynx and trachea can lead to segmental narrowing because of collapse and fibrosis **(van den Broek, 1997).**

Histologically there is degeneration of the cartilage due to invasion by inflammatory tissue. Several authors have described the microscopy of these lesions. It seem that the process is preceded by degeneration of the marginal chondrocytes, The ground substance of the cartilage becomes acidophilic and erosion by inflammatory tissue takes place around the cartilage and compression of the lacunae can be found (Valenzuela et al., 1980).

(II) Wegener's granulomatosis

Friedrich Wegener, 1934, first described what is called (rhinogenic granulomatosis) as a unique clinical entity. By 1954, formalized diagnostic criteria for Wegener's granulomatosis (WG) were established; these included involvement of the respiratory tract with necrotizing granulomatous inflammation coincident with focal necrotizing glomerulonephritis and varying degrees of generalized vasculitis (Godman, and Churg, 1954). Subsequently, the concept of limited WG has become well accepted as different authors

documented its characteristic morphologic and histopathologic characteristics in isolated anatomic sites (Cassan et aL, 1970). Probably 25% of the patients also develop laryngeal manifestations during the course of the disease. The larynx is rarely the source of the primary disease. The lesion usually lies in the subglottis and may cause laryngeal obstruction. The mucosa is swollen, has a granular appearance and bleeds easily on touch (Terent et al. 1980).

(III) Larsen's syndrome

Larsen's syndrome was first described by Larsen Schottstaedt, and Bost in 1950(Larsen et al., 1950). It is characterized by prominent forehead, depressed nasal bridge, hypertelorism, dislocation of the larger joints, and malformation of hands and feet, (Jones, 1988). Both autosomal dominant and autosomal recessive inheritance have been described (Me Kusick et al., 1994).

Laryngomalacia in association with Larsen's syndrome was reported by latta et al., (Latta et al., 1971) tracheomalacia by (Grundfast et al., 1981), bronchomalacia by (Rock et al., 1988). Growe et al., 1989, reported a case of mild, proximal tracheal stenosis, which could be managed by means of tracheostomy.

(IV) Amyloidosis

Laryngeal amyloidosis is rare. It may be part of generalized amyloidosis with involvement of many organs, in particular the heart, kidneys, gastrointestinal tract, liver and blood vessels. There are two main forms. Type A is the secondary type which is found in patients with longstanding inflammatory diseases; type B is the primary type which is sporadically found in the larynx (Lewis et aL, 1992).

The clinical presentation of amyloidosis in the larynx is not characteristic. It may present as a solitary polyp on the vocal cord or as a more diffuse swelling in any region of the larynx or even trachea. Ulceration is not found. However, in rare instances there can be extensive infiltration from the larynx into the trachea, with progressive obstruction of the airway (van den Broek, 1997).

3- Laryngeal Neoplasms

Chondroma and fibroma, can cause laryngeal stenosis because of tumour infiltration or secondary to perichondritis, post radiation perichondritis, or post surgical scarring and stenosis (Pearson et aL, 1986).

4- Congenital Subglottic Stenosis

By definition, a stenosis in a patient with no history of airway manipulation is considered congenital laryngeal stenosis (CLS) . It is estimated that in the pediatric population , less than 5% of laryngeal stenosis is congenital in origin . The types of subglottic CLS anomalies have been classified on anatomic studies of banked laryngeal specimens . One type is the circumferential cartilaginous cricoid stenosis, resulting from a reduced but normal shaped cricoid that produce an excessive narrowing for the patient age and weight (Tuker et aL, 1979). The remaining types of cartilaginous stenosis involve abnormal cricoid shapes. The inferior cricoid ring may fail to expand in its transverse diameter, resulting in an elliptical shape rather than the usual circular ring (Holinger, and Oppenheimer, 1981). The cricoid ring may have a circumferential cartilaginous thickening intruding on the lumen. Alternately, the cricoid may have a localized thickening, resulting in an anterior or posterior lamina .A " trapped tracheal ring " results in a subglottic stenosis when a portion of the first tracheal ring telescopes within the lumen of the cricoid cartilage. This can produce an indentation on the anterior subglottic lumen . Intraluminal CLS has been demonstrated as resulting from submucosal mucous gland hyperplasia or submucosal fibroses. This lumen compromise occurs primarily on the posterior wall (Stell et al.1985).

Congenital subglottic stenosis can also be associated with other laryngotracheal lesions. The most common neonatal airway lesion., Laryngomalacia, is commonly seen in conjunction with congenital subglottic stenosis. Rarely, tracheal stenosis with complete tracheal rings may occur with subglottic stenosis (Holinger et al.1976).

5- Idiopathic Subglottic Stenosis

Idiopathic subglottic stenosis (ISS) is a rare, slowly progressive inflammatoiy process of unknown cause, limited to the subglottic region and the first tracheal arch and apparently occurring only in females. There are no indicator of precipitant or concurrent disease, either at the time of presentation or subsequently. The features are stridor, dyspnea, sometimes dysphonia, and occasionally life-threatening airway obstruction (Benjamin et al.1997).

An association between gastroesophageal reflux and (ISS) has been proposed based on clinical (Jindal et al.1994), and experimental observations (Little et al.1985) but reflux is certainly not present in all patients. An autoimmune cause has been suggested for some cases (de Vries et al.1992), but remain unproven.

Thus the cause of the condition is unknown.

Diagnosis of Subglottic Stenosis

1- Clinically

A~) History:

As in all of medicine , the history and physical examination are of fundamental importance. The various etiologies for airway obstruction should be in mind to determine the exact cause of the laryngeal insult in the presenting patient.

The main symptoms are mainly progressive respiratory difficulty with biphasic stridor , vigorous efforts of breathing with supra sternal , intercostal , diaphragmatic^ retraction . Abnormal cry, aphonia or hoarseness occurs when vocal cords are affected. Dysphagia and feeding problems with recurrent aspiration and pneumonia can occur (Cotton, 1984).

It is imperative to determine how severe the patient [4]s symptoms are. This will help you to anticipate the severity of the airway compromise . Is the patient dyspneic at rest or only with exertion? What is the exercise tolerance? Does an otherwise mild upper respiratory tract infection cause the symptoms to worsen? If a tracheotomy is present, is the patient ever able to breath with the tube plugged , and if so , for how long ?

Also one has to ask about any previous attempts to evaluate the airway or to treat the airway obstruction? If so how were these been performed, and where there any complications ?What are the patient's previous anesthesia experience ? Has the patient been ever intubated, and if so, was the intubation difficult or smooth?

Lastly a general review of the systems and past medical history is important to assess the patient's anesthesia risk apart from the airway consideration, (Gardner et al. 1995).

B) Physical examination:

Examination of the patient to determine how difficult will be to access the airway. Note the general body habitus (obesity), oral aperture , trismus , size of the tongue and tonsils , size and shape of the mandible, the flexibility of the neck at craniocervical and cervicothoracic junctions, note the size of the neck and determine the external landmarks .

2- **Radiological studies**

3- **Endoscopic evaluation (direct laryngoscopy)**

4- **Other studies**

Pulmonary function tests with a flow volume loop may also be helpful for judging the location and severity of the airway obstruction. **(Golish J.A. et al., 1980)**

Acoustic measurement of the subglottic stenosis may be useful in measuring airway cross-sectional area to define the site and severity of the stenosis **(Judith et al., 1996).**

Radiological Studies

Imaging of the larynx can be an extremely difficult endeavor. The anatomy is relatively complex , and landmarks are located close to one another . The target tends to move with every breath and every swallow . However, in certain situations imaging addresses questions that the clinician has difficulty in answering and can make a considerable difference in the therapy .

The plain chest radiography (including expiratory phase and decubitus views) remains the initial imaging procedure in most patients; yet the central airways are among the most often overlooked areas on the plain chest radiograph (Berkmen YM, 1984). Once a central airway disorder is perceived on the plain chest radiography or suspected clinically there are a number of radiographic imaging procedures available to evaluate this region further . A commonly ignored method is simple fluoroscopy ,which allows dynamic assessment of changes in the central airways .Other methods include , Xeroradiography , tomography of the larynx ,contrast laryngography , computed tomography and magnetic resonance imaging (MRI).

1- Plain chest X-rav:

An antro-posterior and a lateral view are obtained . The frontal view of die larynx is obtained by using a high Kilovoltage technique (120Kv) and placing 1mm. Copper filter in front of the x-ray tube, this minimizes the bone shadow and enhances air-soft tissue interface, thus delineating die laryngeal soft tissue structures (Weber, 1984). Small areas of calcifications may be seen denoting the site of previous injury (Dedo and Sooy ,1984)

2-Fluoroscopv:

This examination is done with the patient in the sitting position, its main purpose is to assess the dynamics of the larynx during different phonation maneuvers.

Paralysis or fixation of the vocal cords, assessed with phonation “e” and inspiration, represent an important finding before intervention (Weber, 1984), as opening of the ventricles with separation of the true and false cords is accomplished by having the patient phonate “e” during inspiration, thus the level of stenosis can be estimated.

■v—

Phonation of “e” during inspiration, can be recorded on tape for replay or

recorded on spot films, the air-soft tissue interface is increased withlmm copper filter, which can slide in front of a cassette on the spot film device (Weber, 1984).

3 -Xeroradiography

A selenium-coated charged plate is substituted for the usual radiographic cassette before filming in xeroradiography (Mills , 1981). It has better air tissue interface and therefore enhances the edge and gives better documents of soft tissue details than does tomography . It is easy to perform and is not invasive . However , it requires longer exposure time for its completion (Weber ,1984).

Crysdale and Crepeau (1982), reported that although it is undoubtedly the best method for evaluating chronic airway problems in young children, its use should be reserved for more difficult and unusual cases when conventional techniques have been inadequate.

4- Conventional tomography of the larynx

Tomography of the larynx, usually the linear mode with a 40 degrees tube are and 0.63 second exposure, consists of a series of antro-posterior views made in sequence at 5mm. intervals extending from the anterior cervical spine to the anterior part of the thyroid cartilage .

These sections are made during different phonation maneuvers such as quite inspiration, phonation of “e” including reversed “e” (phonation of “e” during inspiration), and modified Valsalva’s maneuver. This reversed “e” maneuver demonstrates the laryngeal ventricles and thereby distinguishes the true and false cords.

Lateral sections may be added for demonstration of lesions in the sagittal plane that are poorly outlined on the frontal view .Linear tomography will show mucosal details , length , and thickness of a stenotic area and vocal cords fixation (Weber, 1984)

More recently helical or spiral techniques have been introduced in CT scanning of the thorax . Spiral CT technique involves continuously scanning the patient during a single breath-hold as the table is fed through the gantry at a constant rate . The result is the acquisition of a large volume of data without the gaps in data that occur from misregistration artifacts possible when multiple single breath-holds are used . Owing to the volumetric nature of this data acquisition, it is possible to reconstruct these data in infinite display planes and even to present the data as a three-dimensional display (Worrell,1995).

Conventional tomography is superior for showing subglottic lesions, and gives more satisfactory demonstration than reformatted CT images in the coronal plane, (Phelps, 1997).

5- Contrast larvngographv

This examination should not be undertaken in a severely compromised airway. Under such circumstances a mild tissue reaction to the media used (liquid barium or tantalum dust) may be sufficient to precipitate airway distress (Zalzal, 1988).

6- Computed tomography

Computerized tomography provides a non-invasive, quick and effective radiologic investigation of the larynx, and is not uncomfortable for the patient. It can be carried out without risk in the face of respiratory obstruction or after laryngeal injury. It gives accurate assessment of the laryngeal anatomy, (Phelps, 1997).

It is of a great value especially in patients with obvious laryngeal fractures or those with large endolaryngeal lacerations (Schefer, 1992)

Computerized tomography of the larynx is now a valuable addition to available imaging techniques. The axial CT sections produce an image similar to the one seen by the surgeon. Respiratory movement is less of a problem with the new fast scanners, but acceptable images can be obtained in quiet respiration with long scanning time. Scanning is begun at die level of the hyoid bone and sequential scans of 5mm slices are made in caudal direction. The shape of die airway alters as sequential scans are viewed. Above die rounded hypopharynx is bisected by the crescentic epiglottis. Further down die median and lateral glossoepiglottic folds delineate the vallecula. Below this the airway assumes a triangular shape and the pyriform fossae are seen as two lateral appendages separated by the aryepiglottic folds. At the level of the cords die shape change to the characteristic glottic chink or boat shape with the sharp anterior commissure extending right up to the thyroid cartilage in the midline .In the subglottic area there an even symmetrical oval shape which gives way at the level of the first tracheal ring to an oval, flattened posteriorly, which may be likened to the shape of the horseshoe, (Phelps, 1997).

7- Magnetic Resonance Imaging (MRP

Magnetic resonance imaging is superior to CT in its capacity for soft tissue

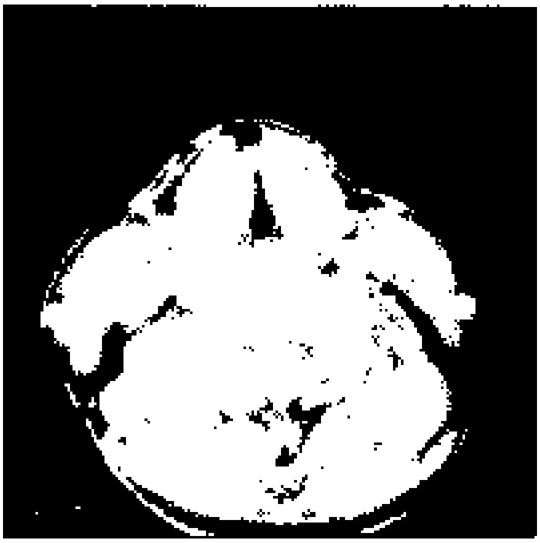
discrimination, its ability to define physiologic and pathologic structures in multiple planes without repositioning of the patient, and the lack of radiation exposure, which allows multiple follow-up examinations to be scheduled without concern. (Schefer, 1992).



Figure 5. Sagittal MRI of the larynx shmving subglottic stenosis.

BH

(A)



(B)



(C)

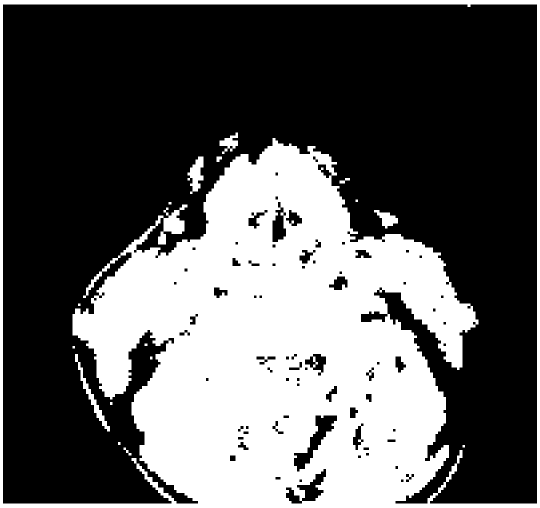


Figure 6. Axial CT of the larynx A) at the level of the vocal cords. B&Q at the level of the subglottic area showing subglottic stenosis.

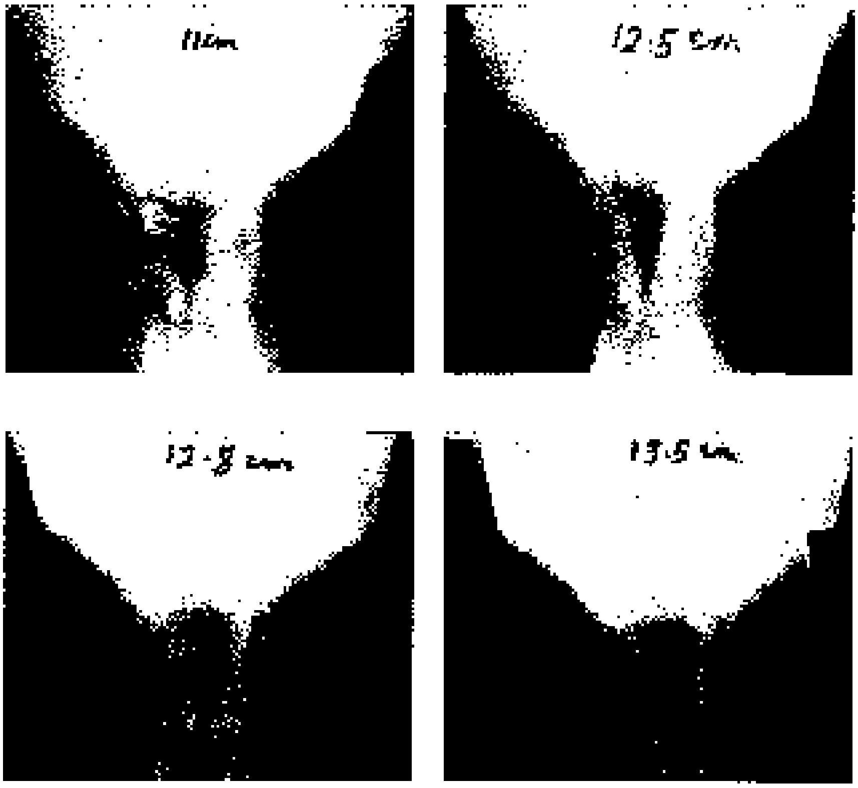


Figure 7. Conventional Tomography of the larynx at different thickness showing

Subglottic stenosis.

Endoscopicpic evaluation by direct laryngoscopy

Operative evaluation of chronic airway obstruction is the most definite component of the diagnostic work-up of this life-threatening problem. Endoscopic evaluation can provide the best assessment of an obstructing lesion and is often the setting for initial surgical intervention .

The invasive nature of this technique , however , may cause the very event we are seeking to avoid : complete acute airway obstruction . Avoiding this dreaded occurrence requires thorough preoperative preparation open communication with all members of the operating team, and anticipation of and rapid response to complications (Gardner et al.,1995).

* Preoperative patient preparation

Common symptoms after endoscopic evaluation of the airway are sore throat and tongue pain. Dislodged teeth are also a possibility , and dentulous patients with difficult access should have custom tooth guards made preoperativeiy.

If the need for tracheostomy is even a remote possibility, the patient should be prepared for and asked to consent to it . In some cases, extubation is not advisable until the patient is fully awake , so die patient should be forewarned of this possibility to avoid panic later . Another potential complication is pneumothorax from jet ventilation (Norton et al., 1976.), and (Rontal et aL, 1980).

* Anesthesia and preoperative medications

Prior to administration of any sedatives or muscle relaxants , the plan for the patient must be discussed with the anesthesiologist . The surgeon should first describe the airway, show photographs, if available, and discuss the expected difficulties and plan if they arise .The surgeon and the anesthesiologist also need to discuss whether the operation will start with the patient breathing spontaneously, whether intubation is possible and will be done at the beginning of the case, or whether the procedure will be done using jet ventilation (Norton, and Strong, 1981).

Dexamethasone ,10mg , and cefazolin ,lg, are routinely administered intravenously prior to beginning the procedure if the patient is not allergic to these medications . Glycopyrrolate may also be helpful for excessive secretions **(Norton, and Strong, 1981).**

^Choice of ventilation:

A- Spontaneous ventilation

It is always helpful to allow the patient to breath spontaneously during the endoscopy. If Laryngomalacia or tracheomalacia is suspected , spontaneous ventilation allows assessment of the airway in a more physiologic state than does assisted ventilation . With an extrathoracic obstruction or collapse , positive pressure ventilation may open up a stenosis that would collapse with normal, negative-pressure ventilation . During this process , it is important to use drugs with amnestic properties **(Gardner et al. 1995).**

B- Assisted ventilation

The choices of ventilatory technique include tracheotomy, transoral endotracheal intubation, jet ventilation (Venturi), and ventilating bronchoscope. Blind nasotracheal ventilation is inappropriate in this situation.

When the patient has a preexisting tracheotomy in place , ventilating the patient through this site is preferred . The smallest endotracheal tube (ET) that provide adequate short term assisted ventilation is preferred, because it permit better visualization of the surrounding structures. A 5.0mm Et suffices for most adults, although a 6.0mm ET may be necessary for obese individuals **(Gardner et al., 1995).**

Unless a preexisting tracheotomy exists, procedures must be done either with jet ventilation through laryngoscope or subglottoscope or with a ventilation bronchoscope. Both of these techniques require easy access to the larynx to avoid loss of control of the airway during induction of anesthesia.

If the stenosis is relatively high , a laryngoscope provides the most room . A telescope can be passed through the scope and glottis for examination of the airway . This technique allows for accurate measurements of location of the stenosis (relative to the glottis) and length of the stricture it may be possible to perform the necessary surgery through the laiyngoscope as well.

If the glottis cannot be opened widely enough with the laryngoscope to allow surgical manipulation (if that is to be done), a subglottoscope is necessary to access the subglottic or tracheal stenosis without damaging the vocal cords . when jet ventilation is performed through a subglottoscope , the jet port is below the vocal cords . This arrangement is more efficient than locating the

jetport above the vocal cords but increases the risk of pneumothorax **(Koufman, et al., 1987).**

^Details of the endoscopic procedure:

As already discussed, the basic principles of the procedures are to perform a thorough examination and avoid an airway crisis. Another point to consider is whether the goal is to evaluate the stenosis and perform no surgical manipulation or whether the endoscopic management is to be initiated. In our practice, we assume that some surgical manipulation (usually with the C02 laser) will be done, and we proceed with that assumption, to avoid delays later if we decide to perform surgery during the endoscopy.

From the beginning, one must be prepared to handle an airway crisis. Prior to induction of anesthesia, the endoscopy table should be set up and the light sources plugged in. Suction should be hooked up. Have the endoscope picked up and on the table. A Jackson sliding laryngoscope and a Holinger anterior commissure laiyngoscope are always on the table. Although the Jackson laryngoscope is good for intubation or passing a rigid bronchoscope, the anesthesiologist laryngoscope with a straight Miller blade is probably the best scope for intubation. A tracheotomy tray should always be available in the operating room.

If the patient will be breathing spontaneously during the examination , the shoulder roll and drapes can be placed when the anesthesiologist judges that the patient is at proper level of anesthesia . A tooth guard is used in dentulous patients, and two moist gauze sponges for edentulous patients. The eyes are taped, and wet eyepads are placed over the eyes in anticipation of C02 laser use **(Gardner et al.1995).**

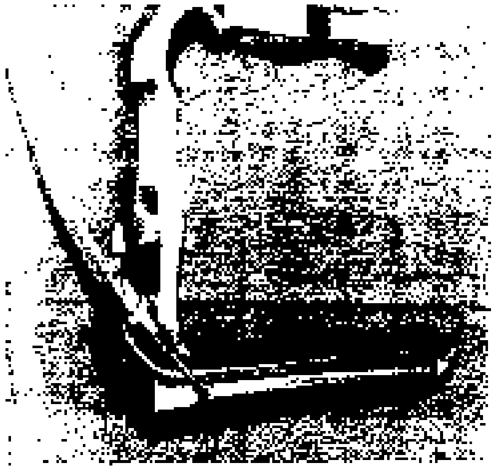


Figure 8. The Ossof-Karlan modified Dedo laryngoscope.

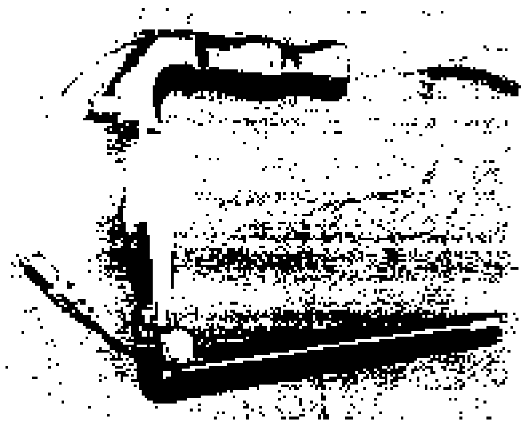


Figure 9. The Ossoff male subglottoscope.

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Figure 10. The O-degree Hopkin's rod telescope is used to examine the larynx A charge-coupled camera allows the examination to he videotaped For later review and comparison of interval examinations.

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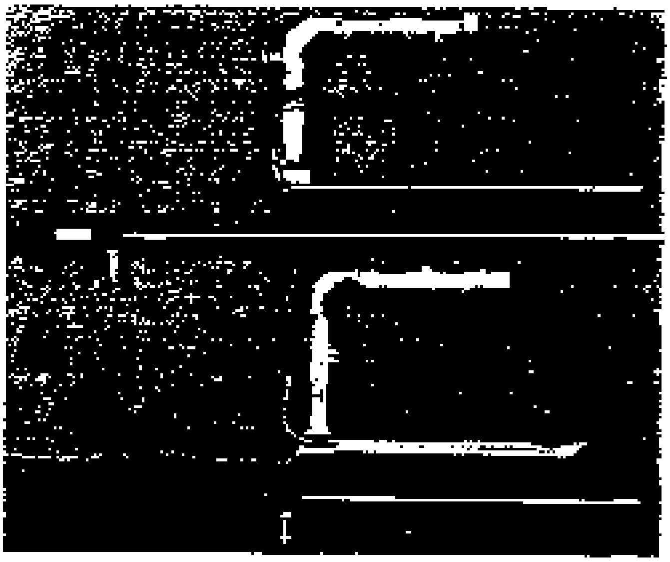


*Figure 11.Hopkin *s rod telescopes are used for examining and measuringThe obstruction.*

The Holinger anterior commissure laryngoscope is used initially to perform a thorough out examination of the pharynx and larynx. This laryngoscope provides the easiest access to the larynx and hypopharynx and distorts the anatomy the least.
After the initial direct laryngoscopy with the Holinger laryngoscope, an attempt is made to pass the largest laryngoscope that will fit. This will provide the most room to work , the best visualization , and the best light . Position the head and neck with the neck flexed and the head extended, and pull the tongue to lift the epiglottis if it is hindering passage of the scope (Rice, 1981).

Measurement of the stenosis is performed with the long bronchoscopic telescope. Key points to be noted are length of the stenosis , the smallest diameter , and the location of the stenosis relative to the vocal cords and tracheostomy site. An easy technique for measuring is as follow:

1- Pass the end of the telescope to the most distal aspect of the stenosis, and mark the telescope at the edge of the laryngoscope with a surgical marking pen.

2- Withdraw the telescope to the proximal end of the stenosis, and mark it again.

3- Withdraw the telescope to the edge of the vocal cords , and make the final mark.

4- Measure the marks on the telescope , and record the measurement.

The diameter can be easily estimated by noting how easily the telescope of known diameter passes through the stenosis (Gardener et al.1995).

The measurement should still be done with the telescope through the laryngoscope, even if the stenosis cannot be seen directly through the laryngoscope (without the telescope).The preceding technique is preferable to using the subglottoscope or bronchoscope ,for two reasons .First, the laryngoscope does not distort the stenosed area at all, and second , other key areas of anatomy , specifically the vocal folds , remain accessible for measurement (Prust and Calkins ,1987).
After examining the lesion with the telescope, bring the microscope into position. Under magnification, palpate the obstruction with either a suction

instrument or a blunt tip probe to determine whether the stenosis is due to hard mature scare tissue or more easily managed soft granulation or early scar tissue .If the etiology of the lesion is unknown, a biopsy should be done to rule out tumor or inflammatory disease (Norton and Brown, 1990).

^Emergence from anesthesia

At the end of the procedure, it is usually safest to have the patient intubated for emergence from anesthesia. If the jet ventilation was not performed through one of the smallest laryngoscopes, the intubation can be performed through the scope to ensure no loss of the airway during the transition .If there is concern that the patient will not be able to maintain the airway until fully awake, do not extubate the patient prematurely and extubation should take place in the operating room with a tracheotomy tray in reach as it is at this time that some patients demonstrate the need for tracheotomy despite the patent appearance of the airway(Prust and Calkins,1987).



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Figure 12-a.Direct laryngoscopic picture of the larynx showing circumferential cicatrical subglottic scaring.

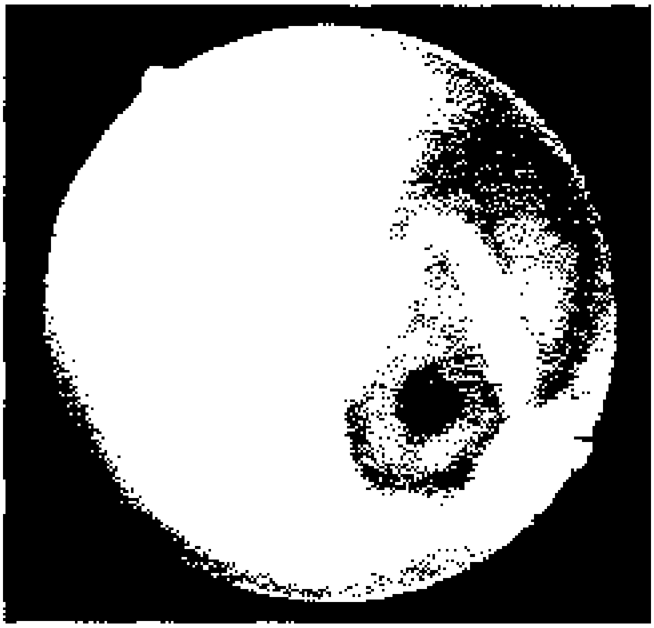


Figure 12-b. Flexible laryngoscopic picture of the larynx shmving circumferential cicatrical subglottic scaring.

Pulmonary function tests

Patients with lesions that cause obstruction of the large airways are often misdiagnosed as having chronic lung diseases or reactive airway disease. Close attention to the history and physical examination provides clues to the presence of laryngeal or tracheal lesions. Obtaining a flow volume loop in the pulmonary function laboratory is a simple and effective method of noninvasively evaluating a patient for the presence of an upper airway obstruction **(Lunn and Sheller, 1995).**

The single best pulmonary function test in the diagnosis of central airway obstruction is the flow volume loop. An appreciation of its characteristic shape and the reasons for its appearance are helpful in understanding alterations in the loop in the patients with airway disease. A flow volume loop is generated by having the patient inhale deeply to total lung capacity, and then forcibly blow out till the lungs are empty, and then rapidly inhale back to the total lung capacity. Flow is plotted against volume; a typical loop is illustrated (fig.). Note that the flow diminishes as lung volume shrinks; no such limitation occurs during inhalation. The reasons for this are complex but derive from the fact that airways are subject to compressive forced during exhalation but are distended by the negative pressures during inhalation. The pressures needed to cause airflow therefore narrow the airways during exhalation and enlarge them during inspiration. The elastic recoil of the lung can be thought of as a force that holds the airway open. Because the elastic recoil of the lung decreases with the decrease lung volume, the airway are subject to greater compressive forces and flow is increasingly limited as lung volume declines **(Mead et al.1967).**

Many numbers can be derived from flow volume loops that are helpful in quantifying and describing the curve. The forced expiratory volume in 1- second (FEV1) is useful in the description of lower airway obstruction. Other variables include the forced vital capacity (FVC), flow at 50% of exhaled or inhaled volume (Vmax50) and the peak expiratory flow rate (PEFR). Although these variables are helpftil in the very common diseases of airflow obstruction involving the more peripheral airway asthma, emphysema and chronic obstructive pulmonary disease (COPD)- they are not as useful in upper way obstruction. In COPD, the flow volume loop shows diminished expiratory flow, especially at lower lung volumes (fig. **2)(Fry and Hyatt, 1960)** There is typical “coving” of the curve resulting from this low flow at low lung volumes.

The loop is quite different when a normal person breathes through a narrowed orifice in the laboratory, thereby simulating an upper way obstruction (Miller and Hyatt, 1969). Miller and Hyatt had normal volunteers breath through

calibrated orifices; an example of such a flow volume loop is shown in fig. 3. As the orifice diameter decreased, flow fell, and there tended to be a " plateau" in flow throughout much of the volume, interestingly, the FEV was reduced significantly only when the size of the orifice was reduced to 6 mm or smaller. In fact, the FEV, and the forced vital capacity were 82.6% and 97.3% of predicted, respectively, in the trial with the 6mm orifice. The maximal voluntary ventilation (MW) and PEFR, however, dropped to 54.7% and 36.9% of predicted, respectively, with the 6mm orifice, leading the authors to conclude that the MW and PEFR might be the most sensitive indicators of early upper airway obstruction. Similar observations have been made by other investigators (Kryger et al.1976). Unfortunately, the MW and PEFR are quite effort dependent and therefore quite variable. The range of normal in a clinical pulmonary function laboratory is so large as to make these tests relatively insensitive to upper airway obstruction. Inspection of the loop is more important than any derived number in diagnosing upper airway obstruction. Estimation of the flow during the plateau can give a rough estimate of the diameter of the obstructing lesion (Gamsu et al., 1980).

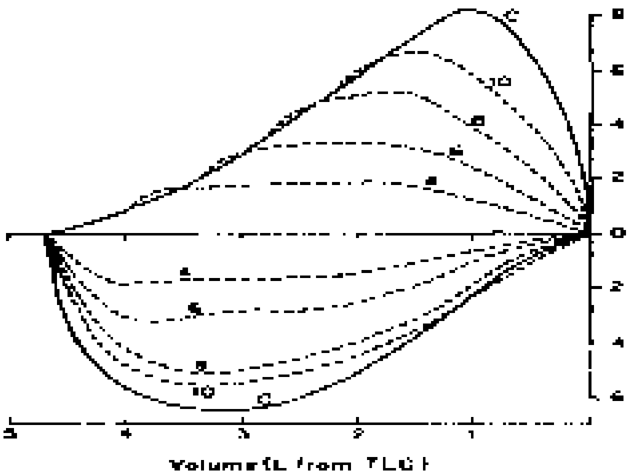


Figure 13. Volume (as liters from total lung capacity) is plotted against inspiratory And expiratory flows. Solid line (C) is the control effort

Zalzal and his associates.,1990, reported pulmonary function tests performed on eighteen children with mean age of seven years decannulated after Iaryngeo-tracheal reconstruction for laryngeo-tracheal stenosis, these include:

- Flow volume loop assessment is an accurate measure because the mid-vital capacity ratio can be obtained from a part of the flow volume curve independent of the subject effort.

- Ratio of forced inspiratory flow at 50% vital capacity to forced

expiratory flow at 50% vital capacity (FIF50/FEF50). Both may be affected in a characteristic way by alternation in air patency.

- Flow volume loops, and FIF50/FEF50 ratio give an idea about the obstruction. When FIF50/FEF50 is less than 1, it is considered significant for upper airway obstruction, while ratio more than or equal to 1 are normal.

- In cases of subglottic stenosis there is decrease in FIF50 and FEF50 with normal FIF50/FEF50 ratio.

- Severity of the obstruction can be derived from ratio of the forced expiratory volume in 1 second (FEV1) to peak expiratory flow rate (PEFR) more than 10 may indicate upper airway obstruction.

- Cases of acquired subglottic stenosis show increase in the specific airway resistance, which is normally, less than 4.5.

- Also there is marked decrease in the maximal inspiratory flow rate (MIFR).

Acoustic measurement of subglottic stenosis

The use of acoustic impulse reflection to measure airway cross-section area (CSA) has been an established investigational technique since its introduction by Jackson et al., (1977) Cross-section areas as a function of distance along the airway can be determined by analysis of a reflected acoustic signal. Primarily utilized to measure total CSA of the distal trachea and lower airways, this technique correlates strongly with actual CSA measurement at specific distances along the tracheobronchial tree. Human and animals studies have been performed to demonstrate this correlation. Techniques used to examine actual airway CSA for comparison with acoustic measurement have included airbronchograms, plain chest radiographs (antroposterior and lateral), and sectioning of negative silicone rubber casts of the tracheobronchial tree (Brooks et ah, 1984). The accuracy of the cross-sectional measurement made by the acoustic method has been demonstrated to the level of the fifth-generation bronchial airways (Jackson, and Olson, 1980). Although the technique of acoustic impulse reflection in the tracheobronchial tree has played a significant role in investigational studies, its use as a diagnostic and prognostic test in the clinical setting has been limited. Only one study to date

has been performed to investigate the utility of this technique in the clinical diagnosis of upper airway obstruction (Hoffstein, and Zamel, 1984).

Management

The goal of laryngotracheal reconstruction is to provide a stable airway with preservation of phonation, an effective cough, and swallowing without aspiration (Eliachar et al., 1991).

Evaluation of the stenosis

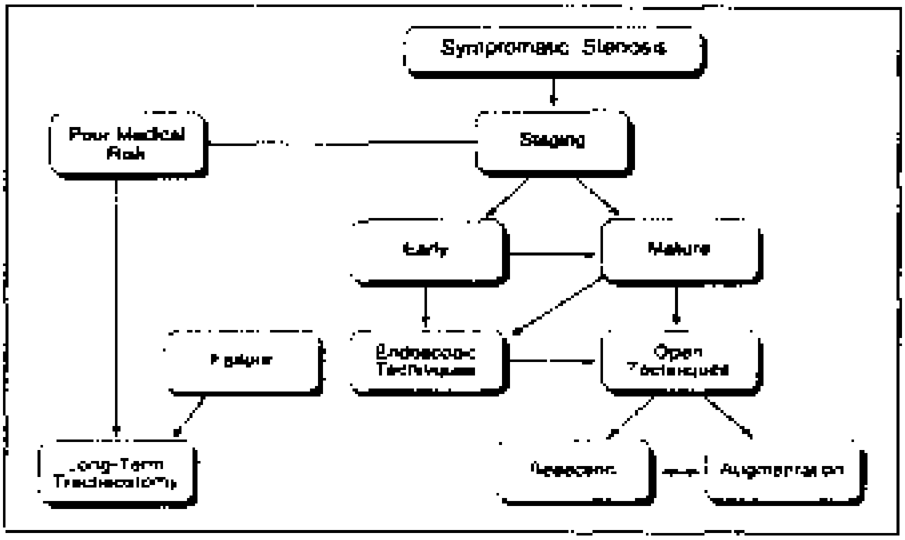
Because patients with subglottic and tracheal stenosis often have other obstructing airway lesions, a complete evaluation must include an assessment of the entire laryngotracheal airway. The lesions may be characterized using four parameters, as shown in table (3).

Table (3). Characterization of obstructing airway lesion.

Location	Subglottic, glottic, tracheal, or any combination
Shape	Thin web versus long stricture Complete versus incomplete circumferential stenosis
Components	Mature, hard scar Soft, nascent scar or granulation tissue Collapsed segment with lack of cartilaginous support Firm but distorted cartilage network
Severity (of obstruction)	
Grade I	<70%
Grade II	70%-90%
Grade III	>90%; lumen visible
Grade IV	Complete

Management of the stenosis

An approach to managing a patient with symptomatic lower airway obstruction is presented in the following algorithm.



This algorithm, however, represents a simplified approach to a complex problem. The pathway chosen depends on a number of factors, including the nature of the stenosis (early or mature), the location, extent, and severity of the stenosis, and the overall medical condition of the patient. In addition the approach depends on the surgeon's experience and preference, because a number of management techniques are available (Wanamaker, and Eliachar, 1995).

The principles of restoring the laryngeal airway depend mainly on the integrity of the laryngeal framework. The cricoid cartilage is the only complete ring in the respiratory tract and is responsible for the patency of the subglottic region, as it is the narrowest part of the larynx and trachea
(Hegazy and Dewidar, 1997).

If the cricoid ring is disrupted, it will contract and, according to PoseuilPs law, the airflow will be reduced by the power of 4. This means that any narrowing of the cricoid should be dealt with at the most minor levels of disability (Stell et al.1985).

I-Endoscopic management

A number of endoscopic techniques have been advocated in the management of lower airway obstruction (Eliachar et al., 1991).

Laser.
Dilatation.
Stenting: T-tubes, intraluminal.
Combination.
Others: diathermy, cryosurgery, and intralesional steroid injection.

Endoscopic methods are especially helpful in emergent cases, in which rigid endoscopy is performed with dilatation to reestablish an airway until more definitive treatment is possible.

Laser therapy

Perhaps the most common performed endoscopic procedure is laser ablation of the stenosis and intraluminal stenting. The stenotic lesions most amenable to this technique are early stage lesions with granulation tissue and mature lesions with short segments of intraluminal fibrosis but no involvement of the cartilaginous skeleton (Wanamaker, and Eliachar, 1995).
Treatment options for the endoscopic laser treatment of stenotic segment include: (Coleman et al., 1995).

- Vaporization and dilatation.
- Excision using a microtrapdoor technique.
- Sequential dilatation of the stenosis using laser radial incision of the stenotic segment.

Management with stents

Stents play an integral role in managing lower airway obstruction, either in the primary treatment or an adjunct to reconstruction. Stents support the compromised airway, permit phonation, and provide access to the airway lumen (Eliachar and Papay,1993).
*Tracheal tubes

Stenting of narrowed or obstructed tracheal segments with a silastic tracheal tube (T-tube) was first reported by Montgomery (1965). He found this technique most useful in-patients in whom previous attempts at laryngotracheal stenosis had failed and in patients who were too sick to undergo more extensive open procedures. When used as the primary treatment, the T-tube maintains the patency of the obstructed tracheal segment from within and allows unrestricted ventilation, unlike solid intraluminal stents. When used as an adjunct to reconstruction, the T-tube supports soft tissue grafts or flaps and an unstable cartilaginous framework (Salssa, and Pearson, 1992).

The prosthesis also provide access to the tracheal lumen for suctioning and irrigation and, when plugged, may allow phonation (Eliachar, and Papay, 1993).

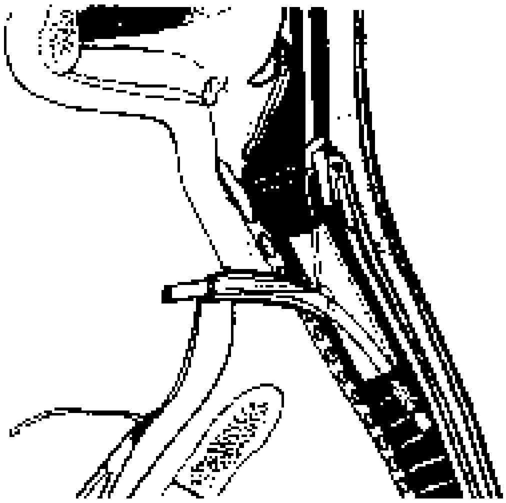


Figure 14. Safe insertion of the T-tube using a 0.5 umbilical tape To guide the tube together with continuous endoscopic Monitoring.

Although the stents are effective in managing lower airway obstruction it is well recognized that they may be a source of irritation with subsequent granulation tissue formation as well as infection. Stents may also break or become dislodged or obstructed with inspissated secretions. These problems occur especially if the stents are not well designed or positioned. (Zalzal, 1992).

<u>* Intraluminal stents</u>

An exciting development that may assume greater importance in managing tracheal stenosis is the indwelling expandable intraluminal stents. At present intraluminal stents are primarily used in the palliative treatment of the advanced tracheobronchial malignancies (Dumon, 1990). The endoscopic introduction of the intraluminal tracheal stents is less invasive than the open surgical management and eliminates the need for tracheostomy and thus its potential problems. The intraluminal stent allow inspired air to be naturally humidified in the upper airway and maintain the normal cough mechanism. Therefore the inspissated secretions are less likely to cause luminal obstruction. Methods to safety introduce and position the stents under direct vision while maintaining the ventilation still are not fully developed, however preliminary animal investigations have reveled additional drawbacks (Mair et al., 1991).

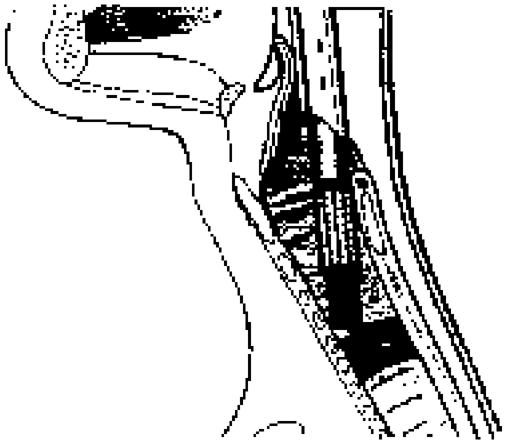


Figure 15. Insertion of an indwelling stent.

Current designs allow soft-tissue ingrowth that restricts removal or repositioning of the stents. Moreover the stents induce inflammatory process at the margins that is characterized by mucosal edema and granulation tissue. Accurate determination of the correct stent diameter is critical, because if the stent is too narrow, migration and displacement could occur, and if it is too wide, adjacent tissue could be eroded (Wanamaker, and Eliachar, 1995).

II- Open surgical management

When endoscopic methods fail or the stenotic lesions are associated with cartilaginous destruction or loss of the tracheal wall support, open surgical procedures are required allowing wide exposure of the pathology and exploration of potentially involved adjacent structures. These open procedures involve either resection of the stenotic segment with end to end anastomosis or airway expansion with bone, cartilage or soft tissue flaps (Me Caffrey, 1991).

*Tracheal resection

Tracheal resection with end to end anastomosis is the procedure of choice for mature isolated segmental tracheal stenosis or tracheomalacia. Although cases of combined subglottic and tracheal stenosis have been managed with resection and primary thyrotracheal anastomosis (Pearson et al., 1986), this form of segmental resection carries substantial risk to glottic function through injury either to the recurrent laryngeal nerves or to the cricoarytenoid joints (Me Caffrey, 1991).

* Augmentation Techniques

The various augmentation procedures are designed to expand the lumen and

provide structural support and an epithelial lining (Petroianu, and Barbosa, 1993):

Costal cartilage grafting.

Hyoid bone interposition.

Sternohyoid rotary door flap.

Composite nasal-septal cartilage grafts.

Sternocleidomastoid myoperiosteal flap.

These procedures are often applied to more complicated cases that involve multiple sites of stenosis or injury. Airway augmentation procedures have evolved from expansion techniques without grafts to expansion techniques with grafts and flaps (Cotton, 1991).

Ill-Long-term tracheostomy

Although the ultimate goal in managing lower airway obstruction is to avoid tracheotomy or to achieve decannulation, long term flap-type tracheostomy is indicated in selected cases. This procedure is indicated in those patients who refuse other intervention, who have not had success with other reconstructive techniques, or who represented poor medical risk. The purposes of this procedure are to bypass the airway obstruction and to maintain phonation and deglutition (Eliachar, and Oringher, 1990) .

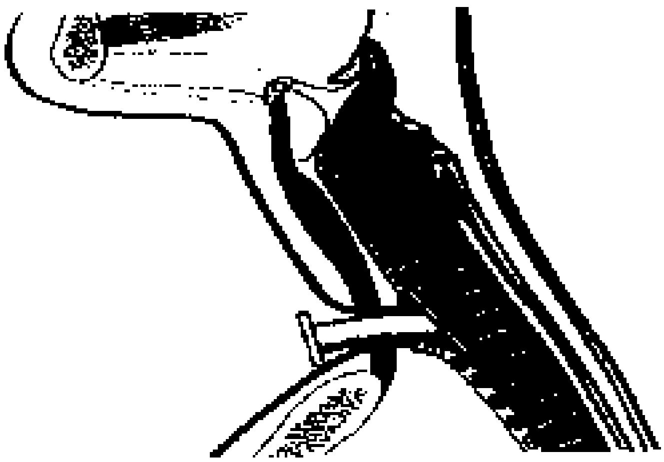


Figure 16. Sagittal view of the laryngotracheal complex with a specially designed tracheostomy stent placed through a long-term tracheostomy.

This technique has also been advocated as an adjunct to laryngotracheal reconstruction. The key function of the long-term flap tracheostomy is to create a self-sustaining stoma with a circumferential mucocutaneous junction that will not collapse or stenose even without the support of indwelling tube or stent (Duncavage et al.1992).

LASER Surgery

LASER is abbreviation of light amplification by stimulated emission of radiation'.

The LASER fulfills the need to manipulate tissues in the distal portion of the airway without necessitating an external incision. Such manipulation may be very difficult using conventional, long stainless steel instruments through the endoscope. The laser, however, can deliver energy to achieve cutting, coagulation, or vaporization with great precision, good hemostasis, and less perioperative edema (Coleman et al.1995).

Laser is a very good method to manage subglottic stenosis, especially when the stenosed segment is less than 1 cm in length. It is an easy way to manage subglottic stenosis as it is done endoscopically, thus saving patients the hazards of external surgical approaches (Hegazy, and Dewidar, 1997).

The type of LASER utilized depends on the type of the tissue or lesion being treated. The type of lesion is important, as are the wavelength of the LASER available and the power density of the energy being delivered to the tissue. The type and color of the tissue, or what chromophores are present in the tissue that will absorb the laser energy, are important considerations in the choice of a laser.

LASER types

There are six types of laser, which are currently in use in otolaryngology- head and neck surgery. These are : Argon, Nd; YAG, pulsed yellow dye, argon tunable dye, KTP/532 and carbon dioxide laser. Many more are still in various states of development (Ossoff, 1986).

In table (4) the more common surgical lasers are listed as well as the distance each of these lasers penetrates into tissues (Reinisch L., 1996).

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LASER	Wave length	Penetration distance
Argon	514 nm	0.8 mm
KTP 532	532 nm	0.9 mm
Dye lasers	577 nm	0.9 mm
NdrYAG	1064 nm	4 mm
Ho:YAG	2100 nm	0.4 mm
Er:YAG	2940 nm	3 um
C02	10600 nm	30 um

Table (4) The wave length and penetration distance of the different types of laser.

Laser delivery systems

Instrumentation for these types of procedures is varied; the standard laryngoscopes are adequate to visualize the supraglottic, glottic and immediate subglottic areas. The microsubglottoscope is necessary, however, if one needs to view the subglottic area or an upper tracheal lesion. Microsubglottoscope utilized for these procedures should have a non-reflective finish internally so that the beam does not reflect off the internal walls of the endoscope, causing damage to areas that one may not wish to injury. There is also a light port for the light carrier as well as a separate suction port and a small port to be used with a jet ventilation cannula .The microspot manipulator is attached to the microscope to deliver the laser energy to the lesion through the endoscope while the surgeon observes with the binocular vision (Coleman, et aL, 1995).

Micro-manipulators

They are used to deliver treatment beams of very small diameter for precision work under the operating microscope. The micromanipulator attaches to the microscope. It accepts output of laser beam and projects the visible aiming beam, as well as treatment beam, onto the surgical site in the field of view of the microscope. Controls on the micromanipulator allow the surgeon to move the beam within the microscope field of view and to change the spot size (Trost, et al., 1992).

Rigid waveguides

These devices provide a way of delivering a relatively small beam through an endoscope or other small opening. Rigid waveguides typically do not provide spot sizes as small as may be achieved with a micromanipulator but they can access tighter places (Trost et al., 1992).

Flexible fibers and waveguides

Shorter wavelengths as those in the visible and near infrared portion of the electromagnetic spectrum allow for passage of the laser energy through a flexible fiber. Some fiberoptic laser wavelengths can be adapted for use with a surgical microscope via a micromanipulator. Standard optical fiber materials (quartz or glass) are opaque at the 10.6 um wavelength of the CO_2 laser. Except at low power and on experimental basis, flexible optical fibres are not available for CO_2 laser (Trost etal., 1992).

Laser safety

Safety is a vital factor common to all laser procedures. Lundergan (1987)

provided the laser safety checklist for any laser surgery; -

Outside control area:

Warning light above door activated when laser is in operation.
Appropriate warning signs at eye level indicating wavelength.
Eye protection available on door appropriate to wavelength being used.

Laser environment:

Eye protection for physician, support staff and visitors, including shutter devices and protective filters.
Instruments on or near beam path properly anodized or protected to avoid reflection.
Windows covered.
Check for water leakage on the floor.
Smoke evacuation system in place.

Patient protection:

Appropriate eye protection.
Surgical drapes moistened where appropriate.

Laser operation:

Appropriate water flow.
Fibro-optic output verified.
Foot switch available to operator only.
Standby mode in use when not actually treating patient.

(A) Carbon Dioxide laser

The CO_2 laser emitting spectral energy in the mid infrared portion of the electromagnetic spectrum (10.6 um wavelength); developed in 1964 by Patel et **al.;** is the most widely used for all surgical lasers.
It operates in both pulsed and continuous wave modes. The laser medium is a mixture of carbon dioxide (5%), Nitrogen (13%) and helium (82%) gases; it is exited by radiofrequency or direct current electricity. The CO_2 molecule is the one vibrating in the lasing process. The CO_2 molecule can vibrate in three independent ways. In the asymmetrical stretch mode it has a relatively long lifetime, which allows the population of molecules in this site to build up. The constitution of a population inversion is a necessary characteristic for the 10.6 um infrared laser transition. The CO_2 molecule in the 'ground[5] level collides

either with fast moving electrons or with excited nitrogen molecules. In either case energy is transferred to the CO_2 molecules causing the molecule to vibrate. It so happens that the vibrating energy levels of nitrogen coincide with the energy of he asymmetric stretch mode COz that eases the transfer of energy. To shorten the lifetime of the Tower[5] level of energy, helium gas was added. Since helium is a light atomic gas, it conducts energy from the lower states and transfers it quickly to the tube walls. It also keeps the discharge temperature relatively low, preventing the build up of CO_2 molecules in the lower laser level.

Since the 10.6 um wavelength of CO_2 is invisible, a helium-neon light is used as a guide **(Patel et aL, 1964).**

The strong absorption of the CO_2 laser by water creates a “what you see is what you get[55] effect on the human tissue which result in a very precise surgical tool. The wavelength of the CO_2 laser is extremely forgiving because the depth of penetration in the tissue is minimal. Output power may exceed 100 watts in continuous operation and peak power can exceeds **500** watts in pulsed operation **(Me Kenzie, 1988).**

The C02 laser operates at 10.6 um which cannot propagate through glass optical fibres and is normally delivered through an articulated arm. Silver halide optical fibres for the CO_2 laser, as well as wave-guides have recently been introduced to the market **(Kao, 1992).**
Strong and Jako, (1972), were the first to use the CO_2 laser delivery system including a micro manipulator that coupled the CO_2 laser to the operating microscope and permitting precise application on the vocal cords.

Its wavelength is 10.6 urn is at the peak of absorption of water. This characteristic is important because absorption of this wavelength into soft tissue (90%) water content will concentrate the energy, permitting little heat to dissipate to adjacent tissue (Shapasy, 1987).

The laser is transformed inside the tissue to a thermal energy, raising the tissue the tissue temperature to 100 c and vaporizing the tissue’s water content. This wavelength make the Co2 laser a precise cutting tool (Shapasy et al., 1988).

Mihasi and his associates, (1976), described that the rapid thermal of the laser energy in the tissues surrounding the incision results in a shallow and predictable tissue penetration with minimal edema. The C02 laser can be focused to create a precise cut and defocused to produce coagulation of small blood vessels.

A recent innovation is the ultra-spot micromanipulator delivery system that can be attached to most C02 lasers in current use and is capable of forming a spot

size of 200 microns at 400 mm focal distance (Crockett, and Reynolds, 1990).

(B) Argon laser

Argon laser has a wavelength of 514 and 488 nm. The excitation medium is ionized argon gas in a sealed laser tube. It is excited by direct current electrical charge. The argon laser is operated in the continuous wave (CW) mode. Ten watts continuous wave machines are available, they generate energy sufficient to raise target temperature hundreds of degrees. It can be delivered through optical fibres. This laser normally has special electrical power requirements and needs tap water for cooling the laser (Ossoff et al., 1994).

The visible color of the argon laser is blue-green. Clear liquids and pale tissue poorly absorb the argon laser energy, while strongly absorbed by hemoglobin and melanin (Parkin and Dixon, 1985).

Disadvantages

It has a low precision effect in term of cutting and vaporization (Shapshy, 1987).

Gillis and his associates, (1984), reported that extensive subepithelial damage occurred with a somewhat variable delayed reaction between the time of application of the laser and the detectable break in the epithelium.

Postoperative edema and acute inflammation lasted for three and seven days respectively. The extent of the injury was 30% greater than the original defect. The unpredictable effect of the argon laser on soft tissues limit its application in airway.

(C) Neodvmium-YAG laser (Nd: YAG)

The neodymium-yttrium aluminum garnet (Nd: YAG) laser at 1.06 urn has the longest penetration depth of any of the surgical lasers. It operates in both Q-switched and continuous wave modes. The CW light can be delivered through optical fibres and can produce power output up to 100 watts. This laser produces a homogenous zone of thermal coagulation and necrosis that may extend 4mm from the impact site. Most Nd: YAG lasers employ a visible beam as an aiming device. This beam appears as a red dot when helium neon is used, and appears in other colors when other gas mixture is used or with different filters. It indicates where the invisible Nd: YAG laser will strike the tissue (Ossoff et al., 1994).

The Nd: YAG laser wave length is well absorbed by pigmented and vascular tissue, which along with it's deep penetration in most tissue , enables it to be a good coagulator (Rebeiz et a!.,1991).

^Disadvantages

Most tissues have a low coefficient of absorption of Nd: YAG laser energy (with exception of hemoglobin and other dark pigments), so a high degree of scattering resulting in a low precision of effect in terms of cutting and vaporization (Crockett, and Reynolds,1990).
Care must be taken to apply the Nd: YAG lasers energy in brief exposures of 1 seconds or less at a power setting below 50W, continuous application of Nd: YAG laser at high power setting may result in a "popcorn effect" which is an explosion of the tissue caused by concentration of energy below the tissue surface that creates an expanding cavity **(Rebeiz, 1991).**

(D) Potassium Titanium Phosphate 532(KTP/532)

It is the newest wavelength to be applied to the laryngeal disease. The laser system produces a visible light with a wavelength of 532 nm. It is well absorbed by pale tissue. It posses the advantage of combining a very small spot size (200 micron) with a delivery via a fibro-optic system. It also has a sharp edge at the aim beam **(Crokett, and Reynolds, 1990).**

Similar to the argon laser, the KTP laser lases at 532 nm in a continuous wave mode and can be delivered through optical fibres. The lasing source is a Nd: YAG laser .The Nd: YAG laser rod is continuously pumped with a krypton arc lamp and Q-switch. The 1.06 um light traverses a frequency doubling KTP crystal yielding the 532-nm green light. Like the argon laser the radiant energy is readily transmitted through clear aqueous tissues, while certain tissue pigments, such as melanin and hemoglobin absorb it effectively. When KTP laser interact with highly pigmented. tissues, a localized coagulation take place

Disadvantage

It does not vaporize as precisely as CO_2 laser **(Crokett, and Reynolds, 1990).**

TECHNIQUE OF CO_2LASER IN SUBGLOTTIC STENOSIS:

General intravenous anesthesia with muscle relaxant is used in most

patients.

Adequate ventilation is achieved by manually driven venturi jet attached to the side arm of a ventilating bronchoscope.

Patients are intubated with the open tube rigid bronchoscope after induction of general intravenous anesthesia and institution of venturi jet ventilation using endotracheal metal tubes.

The CO_2 laser is used at an average power of 10-12 W with 0.5 sec exposure, two length of the wave guide are available, 30and 40 cm, with an outer diameter that insure that the wave guide will fit into the adult size rigid bronchoscope.

Treatment options for the endoscopic laser treatment of stenotic segments include:

- Laser ablation (simple excision)

- Excision using a microtrapdoor technique.

- Radial incision and dilatation.

***Laser ablation**

The types of lesions that are most amenable to this sort of treatment are the early subglottic stenosis with granulation tissue which occur within 3 months from the time of the original injury and have not formed mature scar tissue and stenotic segments less than 1 cm in length (Dedo and Sooy, 1984).

Laser ablation of the stenosis is a common technique that may be combined with dilatation of the stenotic segment, intraluminal stenting or both. Laser energy is delivered through a conventional microlaryngoscope coupled to an operating microscope allowing direct, precise control for scar excision (Coleman et al.1995).

The lesion is first visualized with an endoscope and then vaporized. This can be done either with a rigid bronchoscope and a C02 laser proximally or a fiber delivery system for distal delivery of energy. The latter is very useful in airways very small in diameter, where small rigid endoscopes are needed for visualization which do not allow adequate visualization proximal to the endoscope to permit proximal delivery of laser energy. In such a case a fiberoptic delivery system used in conjunction with a rod lens (in case of rigid endoscope) or a fiberoptic delivery system with a fiberoptic endoscope allow both distal visualization of the lesion and distal delivery of the laser energy in a

controlled fashion (Sapshay et al., 1989).
McGee et al., (1979), presented a basic study of the use of the C02 laser for treatment of subglottic and upper tracheal stenosis in a canine model. Total subglottic and partial upper tracheal stenosis were created and then removed with the laser by completely vaporizing the scar tissue. Two to three weeks later there was moderate tissue edema, little granulation tissue and a patent airway. However, later on there was rapid formation of granulation tissue and restenosis. The histologic examination of the scar revealed marked collagen formation with an epithelial lining of predominately the respiratory type. They concluded that the laser caused a delay in collagen formation. The use of stents or suitable tissue graft was suggested to avoid this complication.

One of the earliest significant clinical repots on the use of the use of C02 laser for the excision of laryngeal scars was presented by Strong et aL, (1979). They used this modality in treatment of 20 patients. Fifteen patients were successfully decanulated, and five cases were considered failures (a success rate of 75%).

Lyons et aL, (1980), reported 6 cases of extensive laryngeal stenosis. All of these cases improved to a certain degree with C02 laser excision and intralesional steroid injections. They recommended avoidance of excision of the circumferential scar at one stage. They performed laser excision of scar tissue first on the most involved site and allowed complete reepithelialization at operative side to occur prior to repeating surgery on the contralateral side.

Koufman et al., (1981), used the laser to excise subglottic scars in 13 patients; adequate airway was established in 10 of these patients, but only 8 were decannulated They used stents in 3 cases and were discouraged by the rapid formation of granulation following its removal and by the fact that the stenosis worsened in 2 cases.

The same procedure was used by Shugar and Biller, 1982,and they reported only 3 successful cases out of 8 patients with glottic and subglottic stenosis.

In contrast to Shugar and Biller report, Holinger, in the same year reported a 100% success rate in 6 cases of subglottic stenosis. These were selective cases in which he excised small segments of subglottic scar on repeated occasions. He also avoided the use of tracheotomy in his patients.
Healy, (1989), reported that in cases of severe subglottic stenosis the entire scarred area may be resected in one session, and a soft silastic sheet is positioned to maintain a lumen. This stent should remain in place for 4- 6 weeks, secured externally with a wire suture held over silastic buttons.

Hegazy and Dewidar, (1997), reported the use of C02 laser for excision of subglottic stenosis in 10 patients. Six were tracheostomy dependent and seeking decannulation. The patients were 6 males and 4 females. Their ages range between 12 and 40 years. The cause of the stenosis in three patients was prolonged laryngeal intubation, four were post scleromatous and three were post-traumatic. Improvement in respiration was noticed in 8 patients for a period of six month. Decannulation was done in 4 cases out of the 6 cases with tracheostomy. Failure of decannulation occurred in 2 cases. All cases without tracheostomy improved.

If clinical improvement is not evident by the 3^{rd} to 5^{th} laser application, then further applications is of no value. The surgeon should search for another reason as unrecognized vocal cord paralysis, significant loss of cricoid or tracheal cartilage or unrecognized inter-arytenoid scaring (Crockett and Reynolds, 1990).

*Micro-trapdoor technique

Dedo and Sooy, (1984), were pioneers in reporting a technique for preserving the overlying mucosa when excising laryngeal scars by creation of micro-trapdoor (MTD) mucosal flap. This procedure utilizes the accuracy and tissue preservation capabilities of C02 laser to develop mucosal micro-trapdoor flaps, which could provide mucosal coverage of the area to prevent further stenosis. They were able to decannulate or significantly improve the airway in 17 of 19 patients with posterior commissure or combined lesions.

The micro-trapdoor technique is useful in debulking stenotic areas that are confined to a single quadrant of the airway but may also be used for circumferential stenosis (Werkhaven et al., 1993).
^Technique; (after **Dedo and Sooy, 1984)** -General anesthesia is delivered either through endotracheal tube wrapped with an aluminum tape passed via the mouth or through the tracheotomy tube if present.

-If no tracheotomy is present, anesthesia is administered intravenously, with ventilation maintained by the venturi system via the ventilation channel on the Dedo-pilling laser laryngoscope.

-The tip of this laryngoscope, slightly separating the vocal cords, permits good ventilation and visualization of the subglottic area.

-The procedure is performed by making a crescent-shape incision on the superior aspect of the stenotic shelf. The laser used is a fundamental- wavelength instrument such as the C02 laser. It is used at 5 W in the repeat mode with a 0.02

to 0.1-second pulse duration.

-Once the incision has been made through the mucosal membrane, a microelevator is used to elevate a mucosal flap. The flap is elevated from the superior edge of the stenosis to its inferior aspect; laser is then employed to vaporize the scar tissue forming the stenosis, in submucosal plane proceeding distally.

-Once the scar tissue has been vaporized, the flap is laid back down and gently positioned. If tenting occurs, the flap can be incised with the laser or microscissors at each end of the horizontal incision in a superior to inferior direction, thus releasing the flap.

-One may take the laser beam in a slightly defocused mode and milliwatt power setting to weld the edges of the incision back together, allowing the flap to maintain good anatomic position **(Coleman et al., 1995).**

-This procedure may be repeated as needed. It may also be performed sequentially in different quadrants of a stenosis to treat circumferential stenosis in a staged fashion **(Werkhaven et aL, 1993).**

Duncavage and his associates, (1985), advocated the micro-trapdoor technique and reported the use of C02 laser in treatment of twenty patients with supraglottic, glottic and subglottic and combined laryngeal stenosis. Eleven patients had significant airway improvement or decannulated. They also concluded that circumferential scarring, wide scar with a vertical depth of one cm or more and arytenoid fixation were associated with high degree of failure.

Beste and his associates, (1991), treated twenty patients of laryngeal and tracheal stenosis by multiple (MTD) technique using the C_{02} laser. The airway improved in nineteen patients and decannulation occurred in fourteen patients.

Werkhaven and his associates, (1993), reported that the extension of the (MTD) technique to the pediatric and neonatal subglottis had been limited by the large spot size of the conventional CO_2 lasers. But, the recent introduction of the microspot micromanipulator for the CO_2 laser with a 250 um-spot size enables the accurate development of the (MTD) flaps in limited surgical exposures. They had used serial (MTD) flaps in the excision of the subglottic scar tissue in eight children. Successful decannulation was achieved (figures (17)) in seven patients. They also reported that circumferential scar was not a contraindication for the technique.

Figure 17.

A-B, The laser is used to make an incision on the superior aspect of the stenotic shelf.

C-D, The flap is elevated distally.

E-F, The scar tissue is then vaporized in a submucosal plane

G-Hy The flap may be incised laterally to avoid tenting.

I-J, The edges of the incision may be laser welded back togther.

*Radial incision and dilatation

Shapashy and his associates, (1987), introduce an alternate mucosapreserving laser technique. They reported five patients with severe fibrotic subglottic and upper trachea stenosis. These patients were treated by endoscopic radial laser incisions and dilatation using both CO_2 and Nd-YAG lasers. Their technique involved radial laser incisions of circumferential scar tissue that released the cicatrix or band like stenosis, followed by gentle dilatation. The small bridges of remaining epithelium were helpful in preventing recurrence of stenosis. This procedure is generally performed on lesions more distal in the airway, such as the trachea itself.

^Technique:

-A fundamental wave length laser such as CO_2 laser is used. Coupled to a rigid ventilation bronchoscope, the laser is used in an intermittent mode and with a power setting of 6W through 30cm bronchoscope or 10W through a 40cm bronchoscope **(Coleman et al., 1995).**

-Approaching the lesion endoscopically, one makes radial incisions with laser beam through the stenosis in five or six areas. This will break up the scar band and leave islands of intact mucosa.

-A telescope or a narrower endoscope is pushed through the stenosis, pushing the soft tissue peripherally.

-One should not push into the areas that were incised, but rather on the areas that still have intact mucosa. It is important to maintain intact areas of mucosa to prevent circumferential denuding of the stenotic area.

-Having circumferential denuded areas of mucosa increases the likelihood of restenosis during the healing process and has the potential of making the problem worse.

-This procedure generally needs to be repeated more than once before a stable airway can be achieved. As a general rule the area is allowed to heal for 3 to 4 weeks before the procedure is repeated **(Shapshay et al., 1988).**

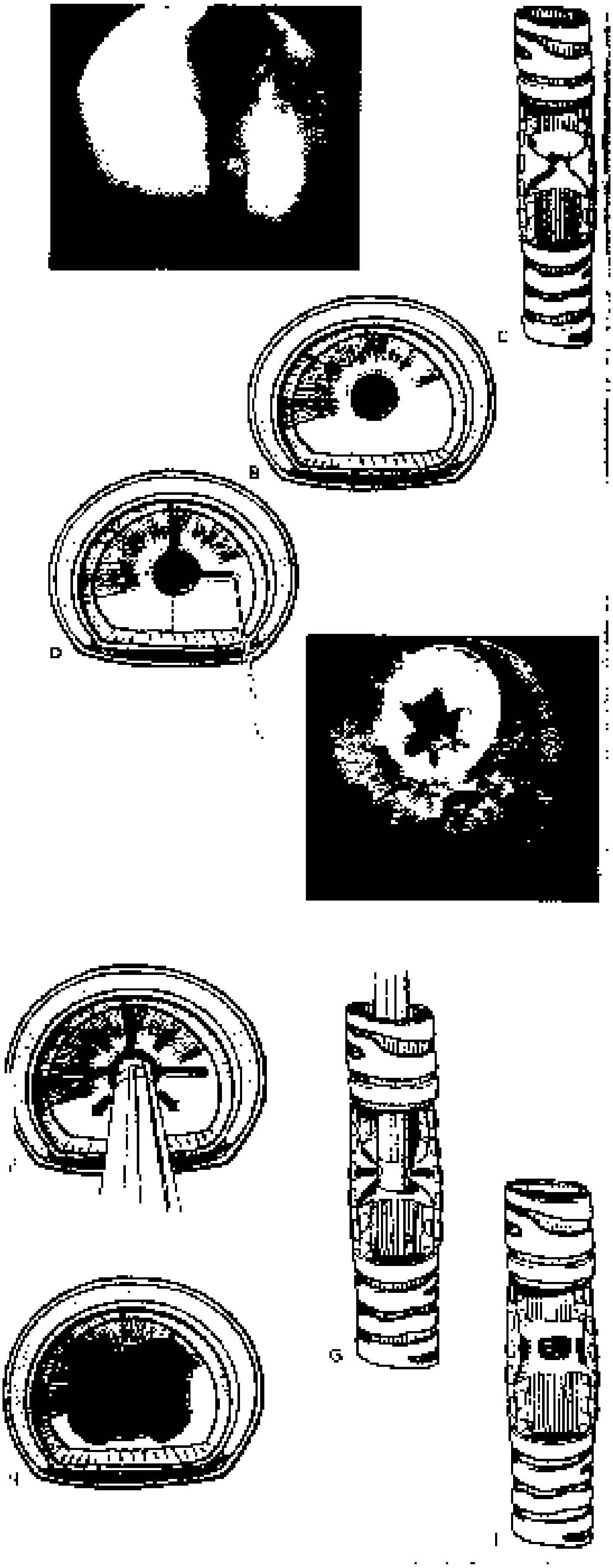


Figure 18.
A) Clinical photograph of proximal tracheal stenosis. B-Q Circumferential tracheal stenosis that would be amenable to radial incision and dilatation.
D~E) Radial incisions are made with the laser.
F-G) The stenosis is then dilated.
H-I) Careful dilatation results in an open airway with areas of intact mucosa.

^Factors associated with failure of laser management of subglottic stenosis:

The conclusions of Simpson et **al.,** (1982), concerning the predisposing causes of failure were:

-Circumferential cicatricial scarring with scar tissue greater than 1 cm in vertical dimension.

-Posterior laryngeal inlet scarring with arytenoid fixation.

-Combined laryngotracheal stenosis.

-Tracheomalacia with cartilage loss.

-Exposure of perichondrium or cartilage during CO_2 excision, predisposing to perichondritis and chondritis.

-Association of preceding bacterial infection related to the tracheostomy.

Open Surgical Management

Stenosis that are longer than 1 cm, have glottic or extensive tracheal involvement, when endoscopic methods fail or the stenotic lesions are associated with cartilaginous destruction or loss of tracheal wall support, open surgical procedures are required. These procedures involve either resection of the stenotic segment with end to end anastomosis or air way expansion with bone, cartilage, or soft tissue flaps. These open procedures allow wide exposure of the pathology and exploration of potentially involved adjacent structures (McCaffrey, 1991).

The goal of open reconstruction according to Fearon and Cotton, (1984), is to:

- Achieve early decaimulation, and patent airway.
- Minimize detrimental effect on voice.

In general, grade in and grade IV, lesions according to Cotton, 1984, Classification requires open surgical methods.

I-Tracheal Resection and Direct Anastomosis

Tracheal resection with end to end anastomosis is the procedure of choice for mature isolated segmental tracheal stenosis or tracheomalacia. Although cases of combined subglottic and tracheal stenosis have been managed with resection and primary thyrotracheal anastomosis (Pearson, 1986).

Resection of the stenotic area and direct anastomosis of the remaining of the larynx and trachea was described as the best method of management of the subglottic stenosis (Gerwat and Bryce, 1974, Finnegan et aL, 1975, Taha et aL, 1981, Stell et aL, 1985, Rifai, 1989, Hegazy et al, 1992, Grillo et aL, 1992, Har-EI et aL, 1993.)

According to Grillo and Mathisen, (1988), more than half of the adult trachea may be resected and successfully reconstructed. Most of the cases involve shorter segments of the trachea (2 to 6 cm), and resection can be performed through a transcervical approach with out a tracheotomy.

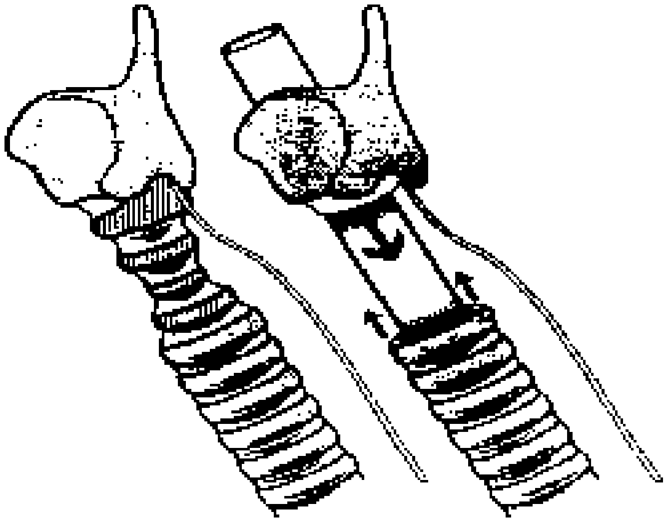


Figure 19, segmental resection of subglottic and tracheal stenotic Lesion and primary thyrotracheal anastomosis

In describing the operation, the authors, named above, agreed that the operation steps are:

-Tracheostomy, if not present, will be done as the first step of the operation and if necessary under local anesthesia. The decision to carry this step under local anesthesia is made if oro-tracheal intubation is impossible, otherwise general anesthesia is induced in the usual way and an oro-Tracheal tube is passed.

-A collar incision is made in the neck and the upper and lower flaps are raised. Rifai, (1989), advised U-shaped horizontal incision with an ellipse of skin to include the abnormal skin and granulation tissue immediately surrounding the tracheostomy site.

-The laryngotracheal complex is then exposed from the hyoid bone to two tracheal rings below the tracheostomy by lateral retraction of the strap muscles and lateral lobes of the thyroid gland after division of the isthmus. The muscle attachments are not divided at this stage.

-The trachea is then opened vertically at the estimated lower limit of the stenosis and the lumen is inspected. If there is obvious stenosis at this level, a further incision is made at a slightly lower level until a normal lumen is found. If the tracheostomy was made immediately below the stenotic area, a lower opening is made leaving a healthy tracheal ring between the new tracheostomy opening and the old one.

- A vertical incision is now made passing from the lower limit of the stenosis

upward to the inferior border of the thyroid cartilage, this step allows the entire subglottic region to be inspected. The upper limit of resection is imposed anteriorly by the attachment of the vocal cord and therefore can not be higher than the lower border of the thyroid cartilage..

-The posterior wall is then incised at a more caudal level, separating the tracheal ring from the esophagus. Retraction of the tracheal ring anteriorly with the finger placed in the lumen and careful dissection of the pericondrium on the posterolateral walls of the tracheal rings will help to identify the recurrent laryngeal nerve (RLN). Incision of the lateral wall is then carried out in oblique direction running slightly downwards. Dissection is continued superiorly between trachea and esophagus to reach the lower border of the cricoid.

-Resection of the anterolateral cricoid arch should be down anterior to the cricothyroid joins. The joints should not be resected. Bryce, (1979), recommended that if the stenosis and the necessary resection extend more proximally, the posterior plate should be shaved at this point so that 50% of its thickness as well as, the outer shell of he cricoid lamina carrying the joint can be maintained. Then the incision continued along the inferior border of the thyroid cartilage. Rifai, (1989), presented a case in which the cricothyroid joint could not be identified due to previous perichondritis.

-Continuity is then restored by end to end anastomosis of trachea to thyroid cartilage anteriorly and the cricoid cartilage remnant posteriorly. The required mobilization to achieve this anastomosis without tension could be accomplished by:

*The trachea is mobilized anteriorly and posteriorly. Extensive lateral mobilization, which jeopardizes the segmental blood supply, is avoided. Care should be taken to avoid damage to RLN mobilization is accomplished in the chest with blunt finger dissection.

*A laryngeal drop procedure is performed by division of the thyrohyoid muscles and membrane at the level of the upper border of the thyroid cartilage. Both superior cornua severed and the upper fibers of the inferior constrictor muscle are divided. This procedure drops the larynx and allow it to tilt forward (Bryce, 1979).

*Flexion of the head allows the two mobilized ends to be opposed.

-By using the above techniques no difficulty has been encountered to achieve anastomosis without tension after resection at the level of the lower border of the thyroid cartilage above, and at the level of the third tracheal ring below (Gerwat and Bryce, 1974, Rifai, 1989 and Macchiarini et al., 1993).

-The laryngeal drop procedure often leads to marked dysphagia in the early postoperative period which may be further aggravated by the presence of a stent. Naso-gastric tube feeding is, therefore, essential for 5 to 7 days.

-After the anastomosis is completed, the pericondrium on the superior border of the thyroid cartilage and the remains of the thyrohyoid membrane are sutured to the muscles of the base of tongue.

-Bryce, (1979), noticed that because of the inequality of the shape and size of the subglottic lumen and the tracheal lumen a silastic stent should be inserted and sutured above and below to the line of anastomosis. The stent projects proximally between the vocal cords and distally into the trachea short of the tracheostomy stoma.

-However, Gerwat and Bryce, (1974), and Machiarini et al., (1993), reported that the use of a stent did not seem to be essential for a satisfactory result in all cases especially where the lines of resection are even and firmly in opposition. Taha et al., (1981) and Maddaus et al., (1992), used a T-tube stent. Rifai, (1989), and Grillo et al., (1992), did not mention the use of stents. The wound is then closed as usual with drainage.

-In the absence of a stent the tracheostomy tube is removed after seven days when the danger of aspiration had passed. Taha et al., (1981) and Rifai, (1989), closed it at the second day and removed it on the seventh postoperative day.
-When a stent is employed, this is left in place for two to three weeks before removal. The tracheostomy can then be removed a few days later.

Disadvantages

This technique has a long list of potential intra-operative, postoperative, and long-term complications (Peskind et ah, 1993). Most commonly, granulation tissue develops at the anastomosis (Grillo, 1979). Other complications are anastomosis disruption, air leak, recurrent stenosis, innominate artery hemorrhage, aspiration, esophageal fistulas, and injury of the recurrent laryngeal nerves. Because the laryngeal position changes, transient dysphagia may also occur. Mortality varies from 10% to 20%, and the morbidity from 20% to 50%. More recent reports have reported fewer complications (Har-El G et al.1993).

Most complications can be avoided by careful surgical technique and meticulous postoperative care. Although some have recommended the intraoperative identification of the recurrent laryngeal nerve, most authors are of the opinion that with careful dissection directly on the trachea, there is no need to identify the recurrent laryngeal nerve (Couraud et al., 1982).

Augmentation Techniques

These procedures are often applied to more complicated cases that involve multiple sites of stenosis or injury. Airway augmentation procedures have evolved from expansion techniques without grafts to expansion techniques with grafts and flaps (Cotton, 1991).

The various augmentation procedures are designed to expand the lumen and provide structural support and an epithelial lining (Petroianu, Barbosa, 1993) they include:-

- Costal cartilage grafting (Muntz and Lusk, 1990, Zalzal, 1993).

- Hyoid bone interposition (Abedi and Frable, 1983).

- Composite nasal-septal cartilage grafts (Toohill, 1981,Duncavage et al., 1989).

- Sternocleidomastoid myoperipsteal flap (Friedman and Mayer, 1992).

- Sternohyoid Rotary door flap (Eliachar et al., 1989).

- Fibular osseocutaneous free flap (Esclamado and Carroll, 1997).

- Pedicled thyroid cartilage flap (Fry et al., 1985).

Costal Cartilage Grafting

The use of cartilage grafts has added another dimension to the treatment of laryngotracheal stenosis; these grafts help to reduce the duration of stenting in case of cricoid splits and long term stenting by filling the gap between the distracted segments of the airway with rigid cartilage. Scar tissue formation is reduced; thus contraction over a rigid stent is not needed, leading to earlier decannulation **(Muntz, and Lusk, 1990).**

^Technique: after (Zalzal, 1993)

- A 2 to 3 horizontal skin incision inferior to the right mammary gland and deepened through the subcutaneous tissue and muscles. The longest straight segment of costal cartilage is removed without consideration to which rib it

belongs. Cartilage is removed with overlying lateral pericondrium, and the medial pericondrium is left intact. If the piece of cartilage is felt to be small and insufficient to allow grafting into the anterior and posterior areas, another piece is removed from nearby ribs.

A subplatysmal apron skin flap incorporating the superior aspect of tracheal stoma is elevated in the neck. The strap muscles are retracted laterally and the larynx and the upper part of the trachea are exposed. An anterior cricoid split and division of the tracheal rings are performed in the midline anteriorly and extended downward to incise the whole anterior subglottic scar and suprastomal collapse (if present). An anterior laryngofissure is done only if the posterior part of the glottis cannot be exposed adequately through the anterior glottic incision or if there is anterior or total glottic scarring. The entire posterior glottic and subglottic scar is divided vertically in the midline, as is the posterior cricoid lamina down to the hypopharyngeal mucosa, which should not be entered.

Scar excision should not be performed and the superior aspect of the incision should not involve the arytenoid muscle. If there are some fibrotic muscle fibres, they can be incised taking care not to incise the whole muscle.

A boat-shaped piece of cartilage with the pericondrium facing the lumen is interposed between the cricoid segments posteriorly and sutured to the cricoid lamina using simple 4-0 vicryl sutures passed through the mucosa, cricoid lamina, cartilage graft, and pericondrium. The pericondrium should be at the level of the mucosa, and the graft should not be protruding into the lumen despite adequate suturing, the graft will not be stable enough because of superior and lateral motion of the cricoid and thyroid cartilage segments during swallowing and breathing.

To avoid graft dislocation and extrusion into the lumen stent is necessary. The general guide lines for stenting should be followed and include the use of short stent when there is no tracheal lesion and a short stenting period is indicated (4-5wks). The long form of stenting is indicated whenever there is an accompanying tracheal lesion or a long stenting period is needed, which is usually more than 2 months.

After placement of the stent, a cartilage graft is placed anteriorly. If a laryngofissure was performed, it should be closed before the graft is fashioned. The graft is fashioned in a modified boat shape that will allow flanges at the superior and inferior edges of the graft to remain above the

cricoid and tracheal cartilage level and prevent prolapse of the cartilage into the lumen.

The graft is sutured by using interrupted horizontal mattress sutures running from the cricoid and trachea into the cartilage graft in the subperichondrial level and back through the cricoid and tracheal cartilage, this technique of suturing will allow partial eversion of he cricoid and tracheal cut edges and prevent prolapse of the graft, it will also allow the pericondrium to be at the level of the mucosa.

Costal cartilage graft interposition has become one of the favored augmentation techniques when stenotic lesions involve the trachea and subglottis. McCaffrey, (1991), reported that sixteen of twenty one patients were successfully managed using this technique; success was defined as decannulation and patient's ability to perform activities of daily living without restriction. This technique has been modified to allow surgical correction with a one-stage procedure (Seid et al., 1991).

Disadvantages

The complications in this technique are mostly due to stenting. Recurrent infection and granulation tissue formation may occur at the tip of the stent , other complications include postoperative pneumothorax and pneumomediastinum (secondary to air leak around he tracheotomy). Most of the patient may exhibit postoperative voice disorders (hoarseness, breathiness) with excessive pharyngeal muscular tension and aberrant respiratory patterns of phonation, such as clavicular elevation, reversed breathing and excessive phonation beyond a breath **(Zalzal,** 1993).

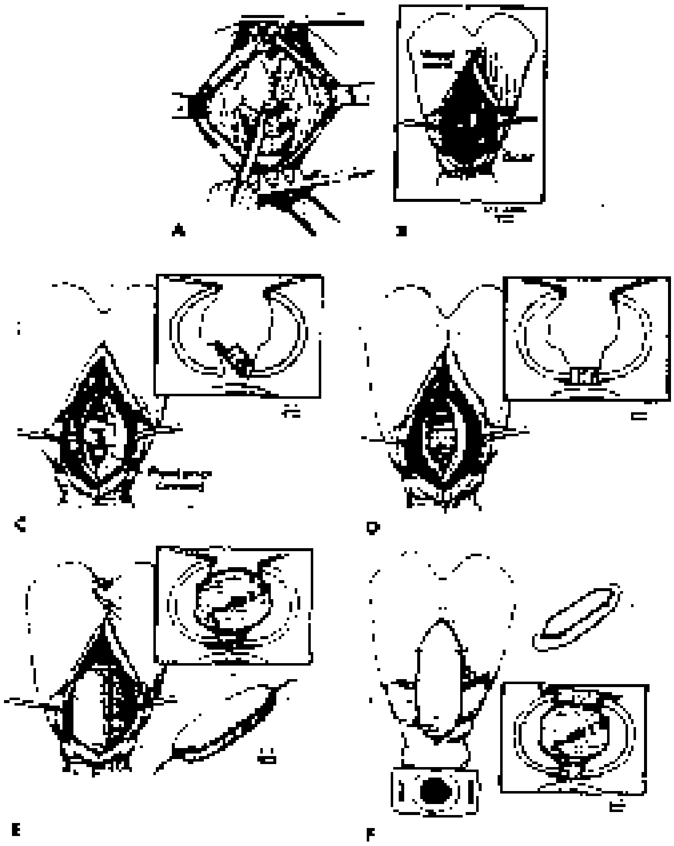


Figure 20, Techniques..

A) Retraction of the strap muscles and exposure of the larynx and trachea.
B) Retraction of the divided anterior cricoid ring and exposure of the stenotic segment
Q Placement of the posterior cartilage graft after division of the posterior lamina of the cricoid cartilage.
D) Posterior cartilage graft in place, no fibrosis or mucosa is excised
E) Placement of finger cot stent covered with split-thickness graft
F) Placement of cartilage graft in anterior defect of the subglottis.

Hyoid bone interposition

After World War I, numerous cases of traumatic cicatricial laryngeal stenosis were treated by Rethi, (1956). He performed laryngofissures and bilateral division of the cricoid plate at the junction of the posterior and lateral walls. Ultimately, Rethi used a single posterior midline vertical incision in the cricoid plate and distracted the cartilage until the convex fibrous wall of the esophagus was visible in the midline. A dilator is left in position while wound healing occurred. In contrast to Rethi, Jackson, (1957), felt that incision of the cricoid plate and the posterior laryngeal wall were disaster to be avoided if possible.

Looper, (1938), described the use of free autogenous hyoid bone in the repair of laryngeal stenosis, the procedure failed and was not used for three decades.

AIozo and his associates, (1976), succeeded in using the hyoid autogenous graft and demonstrated the good revascularization with maintenance of ossification and regrowth of the mucosa over the subglottic hyoid grafted area.

Druck and his associates, (1976), used only the central portion of the hyoid bone after resection the suprahyoid musculature and the infrahyoid membrane and musculature. They divided the hyoid bone lateral to each lesser cornu.

Ward, (1977), and Wong and Kasima, (1978), have described the use of vascularized hyoid-sternohyoid muscle interposition which seems to be the logic progression of this technique as it offers a vascularized graft for this area.

Taha and his associates, (1981), managed three cases successfully by the hyoid bone transposition technique and recommended their technique as one of the most successful techniques in the treatment of the subglottic stenosis.

Abedi and his associates, (1983), modified Druck's technique. As the central portion of the hyoid bone was inadequate to fill the surgical gap after resection of the scar, they sewed portions of the hyoid bone together with Tevdek or 3-0 wire suture to obtain a large enough piece of bone to fill the surgical defect and stabilize the bone graft.

Freeland, (1986), managed eight cases by using hyoid sternohyoid graft, vertical incision of the posterior lamina of the cricoid cartilage and usage of solid silastic mould. Seven patients were decannulated within four month of the operation.

*<u>Technique:</u> (Druck et al., 1976)

- In describing the operation, laryngofissure is performed, the subglottic tracheal lumen is entered, and the luminal scar is excised which must be excised in full thickness down to the supporting carilage.

- The edges of the incised stenotic area are then inspected and judgement is made concerning the length and width of the graft needed.

- The hyoid graft is obtained by severing the attached muscles taking care to preserve the superior laryngeal and hypoglossal nerves. The hyoid graft is usually obtained mid position between the lesser cornua.

- Abedi, and his associates, (1983), sewed portions of the hyoid bone together to obtain large enough pieces of bone to fill the surgical defect, if the vascularized graft is used (composite hyoid sternohyoid muscle grafts), the sternohyoid muscle is left attached inferiorly (Ward etaL, 1977).

- The hyoid is then trimmed to fit the deficit. Care is taken in order not to bulge into the lumen. The edges of the graft are beveled with Stryker saw so that the tracheal edges can fit into the groove, tiny holes are placed in the graft, and the graft is held in position with small wire sutures.

Disadvantages

The only disadvantage are its sometimes awkward configuration (being narrow and concave when a greater length is needed) and the need for a small drill to allow suture-fixation of the bone to the existing trachea (Fry et al., 1985).

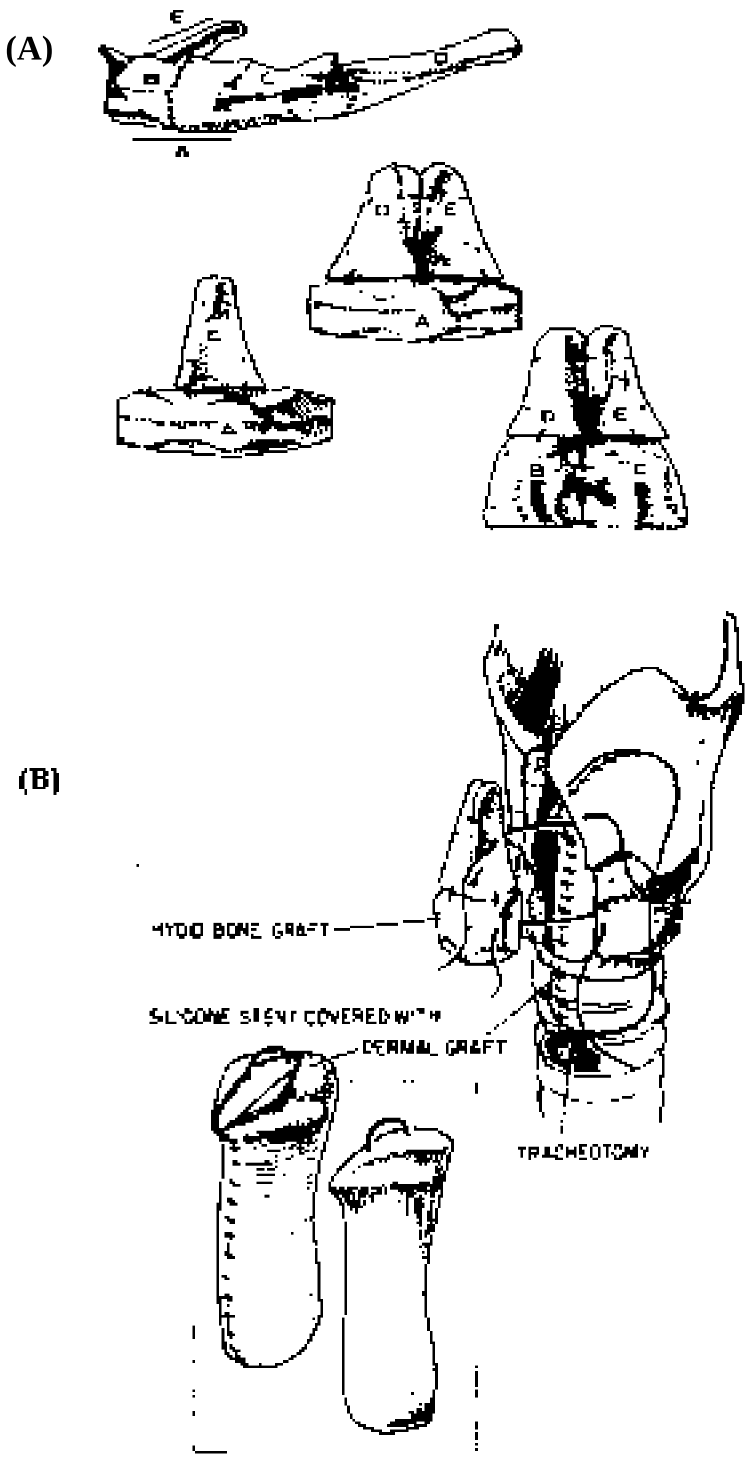


Figure 21. A) Hyoid bone, top; and hyoid bone cut into 4pieces sutured together. B) Conjoint hyoid bone segment inserted into surgical defect, upper right; stent Covered dermal graft, lower left

Composite nasal septal graft

Composite nasal septal graft reconstruction is indicated in several clinical entities. Severe crushing injuries to the glottic region with loss of normal anatomic architecture in the true and false cord regions may be accompanied by partial or complete loss of the thyroid and cricoid cartilages. These types of stenosis are occasionally seen following partial laryngectomy. The second entity is the subglottic or high tracheal stenosis at or above the second tracheal ring. Surgical resection of lesions in this area frequently results in restenosis with injury of to the recurrent laryngeal nerves. Last, these stenotic lesions occurring in the trachea following resection with end to end anastomosis and the anterior tracheal deformity following tracheostomy are ideal for nasal septal graft repair **(Toohill, 1979).**

^Technique: **(Toohill, 1981)**

After the level and extent of the stenotic segment have been carefully assessed by radiologic and endoscopic evaluation, a thyrotomy approach is used to expose the anterior laryngeal and tracheal airway. A vertical incision is made through the stenosis in the midline by sharp dissection. This incision should be extended inferiorly at least 0.5 cm below the stenosis into normal trachea. Superiorly, it can be extended through the anterior commissure to the level of the false cords. The stenosis is observed and measured.

Gentle lateral retraction without damage to mucosa can be accomplished by using a small self-retaining retractor. There is a tendency to totally resect scar tissue at this time. Wide resection should be avoided. On occasion, a vertical incision posteriorly through the cicatrix will allow better exposure anteriorly with the space for a larger graft.

The composite nasal septal graft is now obtained utilizing routine septoplasty instruments and technique. Grafts as large as 3 cm by 5 cm can be obtained from the nasal septum. However, reconstruction rarely require a graft this large.

The septal incisions are tailored to the size of the graft needed. The graft includes mucosa, perichondrium and cartilage preserving the opposing perichondrium and mucosa. The anterior border of the graft is noted and tagged for proper orientation of the mucosal ciliary activity.

A dermal graft, 0.15 thickness is obtained from either the lateral high or anterior abdomen and is fashioned to cover the septal defect.

The nasal septal graft is then fashioned in an elliptical shape and placed in the incision. The anterior portion of the graft is placed inferiorly in the defect for orientation with the normal ciliary movement of the respiratory mucosa, and a 3-0 and 4-0 interrupted polypropylene sutures are used depending on the thickness of the septal cartilage. They can be placed submucosally up to 1 cm apart. A few well-placed sutures assure better viability for the graft.

Ossoff and his associates, (1989), concluded in their study upon sixteen patients with lesions of the larynx and/or trachea that the composite nasal septal cartilage graft can be used successfully in patients with stenosis of the larynx and upper trachea. Stenosis up to 3cm in vertical height can be augmented by the composite nasal septal graft. The respiratory epithelium on the composite nasal septal graft provides immediate resurfacing with a match of epithelium to the stenotic area. Although five patients in this report were not decannulated, reconstruction of moderate sized defects of the larynx and upper trachea with composite nasal septal cartilage grafts is an excellent choice for adult patients.

Disadvantages

The major disadvantages of this technique, are the complications of nasal deformity or septal perforation, the limited amount of septal tissue available for large stenosis, and the fact that the procedure cannot be repeated when large amount of the septum is removed initially. Also, this procedure may be harmful to developing nasal structures in children (Toohill, 1981).

Fibular osseocutaneous free flap

Esclamado and Carroll, (1997), reported the first successful use of a fibular osseocutaneous free flap to reconstruct a severe laryngotracheal stenosis. The vascularized bone was shown to survive in the airway without resorption during a 2-year period and could be shaped to reconstruct a defect where significant anterior support is needed, irrespective of the length needed.

***Technique:** after (Esclamado and Carroll, 1997)

The stenosis is approached through a midline laryngotcricotracheal fissure to the level of the trachostomy stoma.

The subglottic scar is excised to the level of the cricoid to allow identification of the cricoid remnants and tracheal rings.

A fibular osseocutaneous flap is harvested. The cortex of the fibula containing the origin of the peroneus longus and brevis muscles is removed, preserving the vascular pedicle and the perforating vessels to the skin paddle. A large cutting burr was used to drill out the medullary cavity and to thin the remaining cortex, resulting in a canoe-shaped bone graft.

The graft is then adapted to the height of the defect and the superior aspect of the graft is shaped into a cone so as not to excessively splay the glottic region.

The graft is then sutured into position over a stent that is removed after 6 weeks.

Microvascular anastomosis is performed to the left superior thyroid artery and internal jugular vein and the skin paddle is used as an external monitor.

Disadvantages

The limitations of this technique are several. The bone is insufficient to reconstruct a circumferential defect. There is potential for bone over growth and late stenosis. Finally, the bone graft is not pliable enough to allow for complex contouring of the graft to reconstruct complex laryngeal skeletal defects (Esclamado and Carroll, 1997).

Pedicled thyroid cartilage grafting

The following is another technique for reconstruction of the more extensive subglottic and upper tracheal stenosis. This technique of muscle pedicled thyroid ala has proven advantageous even in the compromised patients. The muscle-Pedicled thyroid cartilage flap carries its own blood supply with perichondrial covering, supplies a large conveniently shaped graft, requires one operative site and one operative sitting (Fry et aL, 1984).

^**Technique:** after (Fry et aL, 1984)

A horizontal incision is placed in the neck midway between the midpoint of the thyroid cartilage and the midpoint of the tracheal defect. Flaps are

elevated deep to the platysma both superiorly and inferiorly. The sternohyoid muscles are separated and retracted. Either the right or left sternothyroid muscles may be chosen to pedicle an ipsilateral window of the thyroid cartilage. The contralateral sternothyroid and thyroid-hyoid muscles are elevated away from their insertion on the thyroid ala, leaving the perichondrium intact.

An incision is then carried through the ipsilateral thyroid-hyoid muscles, underlying perichondrium and thyroid cartilage along the superior aspect of the desired graft, extending it inferiorly along the lateral side of the desired graft (Fig A).

Care must be taken to leave behind an intact margin of the thyroid cartilage, superiorly, laterally, inferiorly, and medially as well as intact an intact perichondrium deep to the intended graft. Absorbable sutures secure the overlying muscle and perichondrium to the cartilage graft.

An area corresponding to the cartilage graft is outlined sharply on the contralateral thyroid cartilage perichondrium, maintaining its medial continuity to graft's superficial perichondrium. This adjacent contralateral perichondrium is then elevated away from its intact underlying cartilage to allow a cut along the medial margin of the adjacent cartilage graft.

A thin periosteal elevator is used anteriorly to displace the cartilage graft away from its inner perichondrium. An incision can then be carried from the deep side of the cartilage window (through cartilage and overlying perichondrium) along the inferior margin of the graft, allowing mobilization of the graft on its muscle pedicle (Fig B).

The contralateral perichondrial flap is folded onto the deep surface of the bare cartilage graft and secured with absorbable sutures (Fig C). The graft can now be swung inferiorly on its muscle pedicle and sutured centrally to expand the stenosis (Fig D).

The level of the stenosis being managed determines whether a tracheostomy tube or a T-tube is placed. Neither tube is plugged for the first postoperative week in an effort to prevent cough displacement of the graft or air dissection of the cervical tissue.

Fry and his associates, (1985), reported that three out of four patients have been successfully decannulated with no evidence of restenosis or collapse during follow up ranging from 6 months to 3 years using this technique.

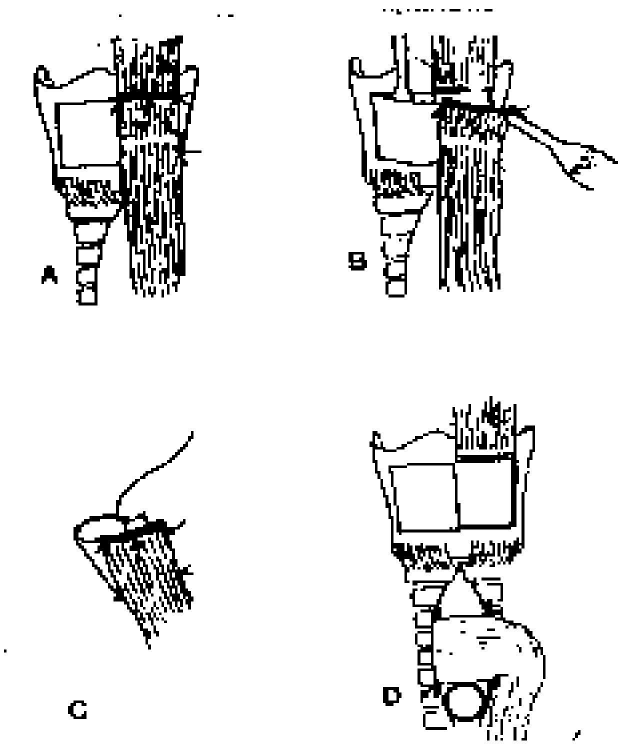


Figure 22. Tracheal reconstruction with pedicled thyroid cartilage.

Sternocleidomastoid myoperiosteal graft

Experience with the sternocleidomastoid myoperiosteal flap has affirmed its use for major defects in laryngeal reconstruction. The flap is available for secondary procedures after its own failure and after other procedure failure (e.g., after hyoid transposition failure). Theoretically, it can be used after any other kind of procedure, assuming that the sternocleidomastoid muscle is intact. It cannot be used after radical or modified neck dissection. The sternocleidomastoid myoperiosteal flap satisfies most of the criteria for an optimal flap, with good long-term results **(Friedman et al., 1987).**

Technique: (Tovi, and Gittot, 1983).

The sternocleidomastoid (SCM) muscle in its inferior part arises by two heads (the medial head from the sternum and the lateral head from the superior-anterior surfaces of the medial third of the clavicle).

To develop a myoperiostel flap, the required amount of periosteal tissue is dissected in continuity with the lateral head of the SCM muscle from the clavicle. The periosteal island is brought over the defective respiratory tract by medial rotation of the prepared muscle pedicle. It is then sutured to perichondrium at the edges of the defect in a way that allows for the outer

periosteal surface to cover the lumen. The juxtaperiostel part of the muscle is folded over and sutured on the reservoir area to provide further support **(Tovi and Gittot, 1983).**

Modification of the technique: (Friedman and Mayer, 1992)

Although the initial procedures were performed with either a horizontal skin incision or an S-shaped incision, it has become clear that there are certain indications for each one.

In patients with a long neck and high trachea or subglottic defects, a distal tracheostomy can be performed with at least three healthy tracheal rings between the reconstruction site and the tracheostomy site. In such cases, the flaps should be designed that the donor and the reconstruction areas are separated from the new tracheostomy site. The s-shaped incision is ideal. The majority of cases, however, involve reconstruction of all of the trachea that can be exposed through the neck, and a distal tracheostomy is not feasible. In such cases, T-tubes are used at the distal area of reconstruction. In such cases a horizontal incision allows ideal exposure.

The second modification deals with transection of the sternal head of the SCM muscle. Since the periosteum of the sternum is difficult to dissect and is small in surface area, it is not useful for reconstruction, the periosteum is therefore not elevated off the bone. The sternal head of the muscle is transected 2 to 3 cm above the sternum to allow rotation of the flap and use of the periosteum for reconstruction.

The third modification involves covering of the clavicle with the pectoralis muscle. The muscle is loosely approximated to fascia to cover the denuded area.

Disadvantages

Granulation tissue formation during the immediate postoperative period is the most frequent complication, other complications include wound infection, aspiration of the stent and partial or complete flap necrosis.

Sternohyoid Rotary Door Flap

During the past decade the rotaiy door flap (RDF), a local vascularized myocutaneous flap, was introduced as a means to reconstruct extensive laryngotracheal defects or stenosis **(Eliachar et al., 1987).**

This bipedicled flap is based on the intact sternohyoid muscle with its overlying skin. When rotated 180 degrees on its long axis it is incorporated readily into the laryngotracheal defect. It derives its blood supply from the superior and inferior thyroid arteries. The venous drainage and neural supply is preserved.

Its unique characteristics are its proximity to the laryngotracheal complex and its dynamic spatial and its physiologic relationship with the airway, which preclude the need for staged procedures or for prolonged internal support **(Eliachar et al., 1989).**

***Technique*: (after Eliachar et al, 1989)**

The neck is extended and the side of the neck least involved in previous trauma or surgery is selected for development of the flap. A vertical paramedian RDF is delineated over the sternohyoid muscle, so situated that it will lie at the proper level and be of sufficient length to correct the anticipant LT stenosis (see Figure a). Two longitudinal skin incisions are made one on each side of the chosen sternohyoid muscle, approximately 2 to 2.5 cm apart. The integrity of the blood supply to the sternohyoid through the superior and inferior thyroid arteries must be preserved. Interrupted absorbable sutures are placed along the margins of the RDF as soon as it has been incised to approximate the skin to the underlying muscle, therefore preventing shearing of the delicate blood supply to the skin of the flap during later manipulations. The midline incision is carried between the strap muscles to expose the thyroid cartilage, cricoid arch, and trachea. An incision is made longitudinally through the stenosis into the lumen of the LT complex (see Figure B).

Scar tissue may be removed submucosally, either from through the lateral wall or through an additional midline incision in the posterior wall. The mucous membrane is replaced after the underlying scar tissue has been removed. Any other appropriate technique such as posterior cricoid split may be carried out. The enlarged lumen is stabilized with an oversized silicone T-tube, the upper end of which

should be at least 4 mm below the glottis. If a glottic stent is needed, one can be fitted like a cork into the upper opening of the T-tube, extending into the supraglottic region. Recently the authors have employed their newly designed vented laryngeal stent whenever appropriate (Eliachar et al., 1987). The oversized stent displaces the walls of the larynx, and the resulting gap is filled by the RDF. The anterior wall of the airway may be reconstructed by the RDF alone or in combination with an epiglottic pull-down (Kennedy, 1986).

It is important to mobilize the sternohyoid muscle along its entire length from its origin at the sternum to its insertion at the hyoid bone (see Figure, C). There is no need to expose the two nutrient arteries that are embedded in areolar tissue under the deep layer of cervical fascia. Release of tension to permit 180' rotation is achieved by careful dissection of the deep cervical fascia on the anterior border of the sternocleidomastoid muscle. Vessels are left intact whenever possible, as preservation of veins is as important, as maintenance of the arterial supply.

The RDF is rotated into position on its longitudinal axis. The flap is trimmed and placed with the skin surface down over the opening in the airway (see Figure, D). Absorbable polyglycolic acid sutures are placed to join the free mucosal edges to the dermal margins of the flap. The sutures are passed through and tagged along each suture line separately, and tied down together with the knots away from the lumen. When necessary, the most inferior portion of the RDF may reach out from within the lumen to form the upper margin of the tracheostomy site. It is sutured to the skin flaps that close the cervical wound.

Suction drains are placed bilaterally. The adjacent neck skin is undermined and advanced medially to cover the defect over the LT complex, and the paramedian incision line is closed in layers. A nasogastric tube is placed and usually can be removed on the second or third postoperative day. Prophylactic antibiotics are used for 48 hours. The stent or T-tube is removed 4 to 6 weeks postoperatively. Following removal of the T-tube, a small tracheostomy tube is placed and corked as tolerated. It can be removed after 7 to 14 days of good airway function with the tube corked. Occasionally, secondary endoscopic procedures are required to trim granulation tissue, especially at the tracheostomy site or along the margins of the intraluminal mucocutaneous junction.

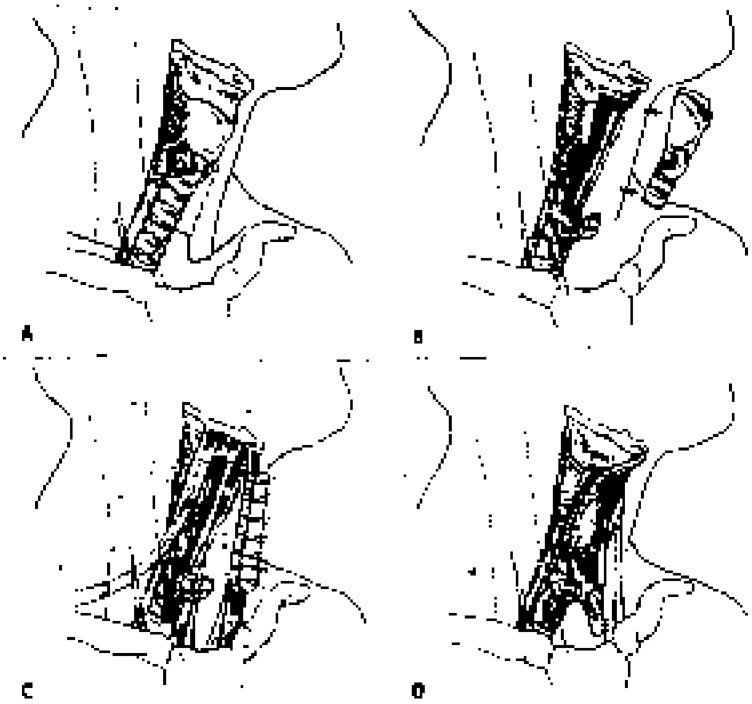


Figure 23. Laryngotracheal reconstruction using Rotary door flap.

INTRAOPERTIVE
Hypoxia

EARLY POSTOPERATIVE
Subcutaneous emphysema, pneumothorax, pneumomediastinum

LATE POSTOPERATIVE Anterior commissure asymmetry/ anterior glottic web	Poor voice	Any, especially anterior laryngofissure	Anterior commissure asymmetry Anterior glottic web Scarred cords	suture). May improve for months. Speech therapy. Reconstruction with keel

Long standing tracheotomy
Persistent mild airway obstruction
Combination anterior laryngofissurre and supraglottic laser surgery

Inadequate airway
Glottic edema
Oversedated
Granulation tissue
Segmental tracheomalacia

Epiglottic petiole prolapse

Arytenoid prolapse

SINGLE STAGE PROCEDURES
ETT obstruction or
[illegible] difficulty
unplanned extubation
[illegible] edema

Pulmonary problems (atelectasis, RSV,RAD infiltrates

BPD = bronchopulmonary dysplasia; CPAP = continuous positive airway pressure; CPT= chest physiotherapy; CTR = cricotrachi resection ; ETT » endotracheal tube; LTEC = laryngotracheoesopfaageal cleft; LTR = laryungotracheal reconstruction;RAD = react! airway disease; RSV = respiratory syncytial virus; SGS = subglottic stenosis; TEF = tracheoesophageal fistula; T tube = Montgomery T tub

Conclusion

Management of the subglottic stenosis has broven to be one of the most challenging and controversial issues in otolaryngology today. It requires a flexible approach that is individualized for each patient. Information obtained from the history and physical examination, endoscopic assessment, and radiographic evaluation guides therapy. The most effective management requires an experienced surgeon who is capable of employing a variety of techniques, from conservative endoscopic procedures to more aggressive open surgical approaches, and who is dedicated to problems involving the airway, voice and swallowing mechanisms. More over the surgeon must recognize the applications, limitations, and complications of the various treatment options.

Endoscopic treatment should be the initial management of a patient with subglottic stenosis who has been properly selected. The types of lesions that are most amenable to this sort of treatment are early granulations that have not formed mature scar tissue and stenotic segments less than 1 cm in length.

Patients who have circumferential scaring, loss of cartilaginous support, stenosis length over 1 cm, glottic or extensive tracheal involvement may be candidates for open surgical procedures for air way salvage rather than closed endoscopic procedures with laser. It is appropriate in some cases, however, to use an endoscopic approach initially to establish just enough lumen to fully assess the airway before planning the type of the open approach.

The open surgical management includes;

•Resection and primary thyrotracheal anastomosis that happen to show very good result being a single-stage procedure, short postoperative period, and minimize the stenting complications.

•Augmentation techniques, these procedures are varied, but share the common goal of providing a stable airway with preservation of normal phonation, optimal reconstruction of the laryngeotracheal complex addresses or includes the following considerations:

1 - The use of pliable materials.
2- The use of fibrous and elastic material for creation of an airtight seal and tension free sutures.
3- The use of rigid materials for preventing of the airway collapse.
4- The use of vascularized material to minimize the possibility of flap necrosis or resorption and subsequent contraction.
5- A single-stage procedure.
6- One surgical field, to reduce the risk of infection and trauma to the patient.
7- A reducible procedure that can be performed with relative technical ease by any qualified head and neck surgeon.

Any reconstruction technique should be weighted on the base of the above criteria as well as the extent and the location of the lesion and the surgeon's preference.

In patients with diabetes, heart disease, or other systemic illness, open approaches must be considered with great care. Such patient may have poor wound healing and poor outcome from an open procedure. They are,. of course, at higher risk for perioperative complications as well. In these situations, simple tracheostomy may be the most prudent choice.

Summary

Subglottic stenosis (SGS) is a challenging complex clinical problem, that has a complex etiology .In the early to middle part of this century, SGS has been frequently sequelae of infection or trauma, but more recently, endotracheal intubation, while providing requisite respiratory support, has precipitated many cases of acquired subglottic stenosis .In addition some children are born with a narrowed subglottic lumen (congenital SGS). Patients may rarely develop stenosis without prior airway manipulation (idiopathic SGS).

Because patients with subglottic and tracheal stenosis often have other obstructing airway lesions, a complete evaluation must include an assessment of the entire laryngotracheal airway.

The plain chest radiography (including expiratory phase and decubitus views) remains the initial imaging procedure in most patients; yet the central airways are among the most often overlooked areas on the plain chest radiograph. Once a central airway disorder is perceived on the plain chest radiography or suspected clinically there are a number of radiographic imaging procedures available to evaluate this region further . A commonly ignored method is simple fluoroscopy ,which allows dynamic assessment of changes in the central airways .Other methods include , xeroradiography , tomography of the larynx contrast laryngography , computed tomography and magnetic resonance imaging (MRI).

Operative evaluation of chronic airway obstruction is the most definite component of the diagnostic work-up of this life-threatening problem. Endoscopic evaluation can provide the best assessment of an obstructing lesion and is often the setting for initial surgical intervention .

Pulmonary function tests may be helpful for judging the location and severity of the airway obstruction.

Recent trials have tried acoustic measurement of the cross-section area of the larynx to define the site and severity of the stenosis, however
The principles of restoring the laryngeal airway depend mainly on the integrity of the laryngeal framework. The cricoid cartilage is the only complete ring in the respiratory tract and is responsible for the patency of the subglottic region, as it is the narrowest part of the larynx and trachea.

The management of the subglottic atenosis involves two main choices:

- Endoscopic management.
- Open surgical management.

Perhaps the most common performed endoscopic procedure is laser ablation of the stenosis and intraluminal stenting. The stenotic lesions most amenable to this technique are early stage lesions with granulation tissue and mature lesions with short segments of intraluminal fibrosis but no involvement of the cartilaginous skeleton.

Stenosis that are longer than 1 cm, have glottic or extensive tracheal involvement, when endoscopic methods fail or the stenotic lesions are associated with cartilaginous destruction or loss of tracheal wall support, open surgical procedures are required. These procedures involve either resection of the stenotic segment with end to end anastomosis or air way expansion with bone, cartilage, or soft tissue flaps. These open procedures allow wide exposure of the pathology and exploration of potentially involved adjacent structures.

Tracheal resection with end to end anastomosis is the procedure of choice for mature isolated segmental tracheal stenosis or tracheomalacia. Although cases of combined subglottic and tracheal stenosis have been managed with resection and primary thyrotracheal anastomosis.

The various augmentation procedures are designed to expand the lumen and provide structural support and an epithelial linning , these procedures are often applied to more complicated cases that involves multiple sites of stenosis or injury, they include:

- Costal cartilage grafting.
- Hyoid bone interposition.
- Sternohyoid rotary door flap.

» Composite nasal-septal cartilage graft.

- Sternocleidomastoid myoperiosteal flap.

Finally we concluded that for better management of these patients, it is therefore necessary that the physician have a thorough understanding of the problem, its causes and die various techniques of management. This knowledge directs the choice of the proper management of every case individually.

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